CLYDE POTTS

Volume 15. Number 3. MARCH, 1901. $3.00 a Year. $1.00 a Number.

JOURNAL

OF THE

New England Water Works Association.

ISSUED QUARTERLY.

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION.

715 Tremont Temple, Boston, Mass.

Entered at the Boston Post Office as second-class matter.

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NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XV. March, 1901. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

ELECTRICAL CURRENT.

BY F. A. W. DAVIS, VICE-PRESIDENT, INDIANAPOLIS WATER COMPANY.

[*Presented November 14, 1900.*]

Lowell says, "There is no work of genius that has not been the delight of mankind." Some would like to add that this depends upon circumstances. For instance, the electric street railway is not wholly a delight to the water-works manager.

I think it long past the hour when any honest, conscientious man, having knowledge of electricity, will deny the destructiveness of escaping electrical currents from city railways to gas and water pipes and other underground interests. Even the managers of street railway companies are now admitting the fact, and in some cases are asking the gas and water companies to help them take care of the current. Such a request is adding insult to injury.

When Benjamin Franklin sent his kite up in the clouds and brought to the earth enough of the current to identify the lightning of the heavens with the electric fluid, he made a great scientific discovery — the greatness of which he never realized. Neither as yet have we seen the full development of it. Generations to come will see a greater development than we have, and will have a better understanding of electrical energy and the nature of it.

To-day we do not understand the nature of electrical energy, but we know some of the laws that govern it, just as we do of heat and light, to which it seems akin in some respects.

While we point to the destructiveness of this current, we must acknowledge its beneficence and the wonders accomplished by it. We are indebted to the current for the smallest light and also for

the great search-light. Its great power is in evidence every day in driving cars and machinery. Its beneficence is manifested in aiding the surgeon in the examination of the human body and the saving of life. To it we owe our facilities for hearing the distant speaker, the music of the glee club and the band, the reproduction of the voice of a man, though he be dead. When a man is condemned to death in the cause of humanity, to use the language of Milton, —

> "Comes the blind fury with the abhorred shears
> And slits the thin-spun life."

The transmission of the human voice so as to be recognized hundreds of miles away, by the means of the telephone, is so common that we cease to wonder at it. Yet it cannot be contemplated without amazement. Franklin may have had some prophetic vision of the greatness of his scientific discovery, but we doubt it. The full knowledge of this all-pervading, tremendous yet subtle energy that makes its way through heaven and earth is yet to come.

While we extol the usefulness and the marvelous work accomplished by the electrical energy, we rightfully complain of the destruction caused by it, which is permitted by those who are using it, and which is absolutely unnecessary. There are, unquestionably, devices and methods of construction that will do away with the destructiveness of the current, and we should insist that those who create the current shall apply the remedy.

It is claimed that the destruction of water and gas pipes by electrolysis is caused by the current leaving the pipe for another conductor. There is no disputing this fact; but we are not certain that there is not some destruction when the current enters the pipe, for the texture of the iron must in some degree be disturbed. For instance, I have found in the case of screw-joint wrought-iron pipe, in which there is an interruption of the current at every coupling, that the iron was pitted not only where the current left the pipe for the coupling and the coupling for the pipe again, but also where it entered the coupling from the pipe and the pipe from the coupling. We do know that when the electric current for lighting passes from the upper carbon to the lower carbon, both are destroyed, the upper carbon much faster than the lower. The burning of the flesh upon the arm, as the current passes along it, shows destruction from the beginning to the end. At times the current passes through the human body,

destroying life and leaving no visible mark of its departure from the body.

Evidence has been found during the past year that there is destruction of our valves on the inside. Plate II, Fig. 2, shows the destruction of a four-inch valve. In addition to this valve we found one hydrant valve so softened that it could be cut with a knife.

Appeals to the street railway companies for relief have been made, with no favorable response, and now in many States the courts have been called upon for relief and protection for the future. A bill has been introduced into Congress protecting the water mains of the city of Washington. During the coming winter there will be bills introduced in the legislatures of several States for the protection of mains in those States. Cities have granted franchises to street railway companies without protective features in them, although with full knowledge of the damage that is being done to underground interests by these stray currents. They have done the same thing where the cities are the owners of the water works. Patent coatings have been exploited as safeguards against electrolysis. If the patent coating will keep the current off the gas and water pipes, why not paint the rails and keep it in them? It would be much less expense, and would fall upon those who should bear it. Experiments have demonstrated that the so-called coatings afford no protection.

Those who doubt the destruction of gas and water mains by the electrical current should otherwise account for the condition of the mains which has arisen since the introduction of electricity as a propelling power; also account for the destruction of wrought- and cast-iron mains in less than twelve months; of lead pipe and wrought-iron services in a few months' time. Expert testimony, while valuable, can have no force as against that of the laborer, who comes in contact with the pipes and sees the actual conditions, — sees the sparks as they pass from one end of the pipe to the other when he separates the ends for repairs; sees the gas set on fire, endangering his life; receives a violent shock when he places his tongs on the pipe, and finds that he is obliged to call upon the street car company to come and relieve the pipe of the current; sees the solder melted on his connections, and the services and mains in the street destroyed; and knows that gas and water produce none of these conditions. It is a waste of time to tell him that he is mistaken, and that there are technical conditions that make it impossible for the electric current to cause this destruction; that it is the result of some condition of the soil,

and that the current on the pipe is of no significance. And so it will be with the courts.

Evidence is abundant that bonding pipe and rail is a failure. Superintendents who are relying upon it for protection will realize in the course of time that they have made a mistake in permitting it. As a conductor, water pipes are as faulty as the railway track is with its bad joints. We are never sure that the metal of the bell and spigot are in touch; in fact, we have reason to believe that they seldom touch. We know that when we use a sleeve, the ends of a pipe do not come in contact, and that the yarn holds the pipe from touching the sleeve. The current leaving the pipe in places and shunting at the joints is evidence that the water mains are not good conductors. Knowing these facts, is it not an absurdity to allow the railway companies to bond rail and pipe? Experience with cast welded joints in the track has proven that they are of no benefit in taking the current back to the dynamo. I have been informed that the water mains in Milwaukee show fifty per cent. more current since the rail joints were welded than before. I am of the opinion that there is an ebb and flow in the current. Whenever the rail or pipe has a greater current than it can carry, for the moment the current flows to the earth, and when the pipe or rail is relieved, the current leaves the earth and seeks the pipe and rail again. I have found abundant evidence in the past year that the current or energy on the pipe, no matter how small, will leave the pipe for a soil which has certain elements in it, and electrolysis is begun immediately.

It has been less than a year since I sent your members ample evidence from all over the country of the destructiveness of the electrical current. Cities that reported no evidence a year ago are now reporting serious destruction. Besides, I do not think there is a member of your Association who, at this time, would question the destructiveness of the current, or the proposition that the street car company, having created the current, is certainly bound in all equity and law to provide for its safe return without damage to the property of others.

DESCRIPTION OF ILLUSTRATIONS.

PLATE I. *Fig. 1.* — Wrought-iron gas service pipes removed from beneath street car tracks, Richmond, Va.

Fig. 2. — Four-inch cast-iron water main removed from Seventh Street, Richmond, Va.

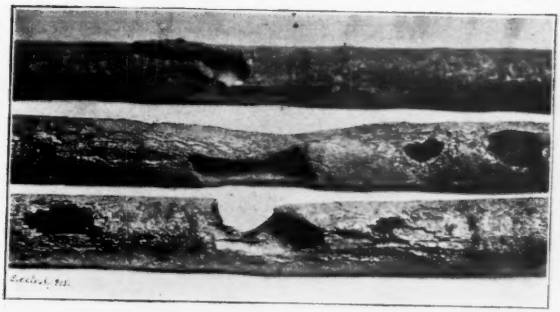

FIG. 1.

FIG. 2.

FIG. 3.

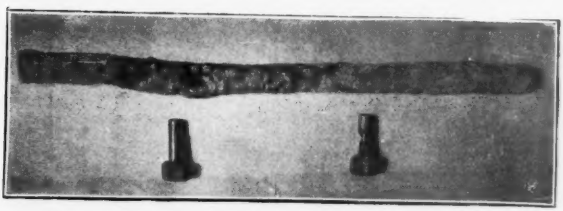

FIG. 4.

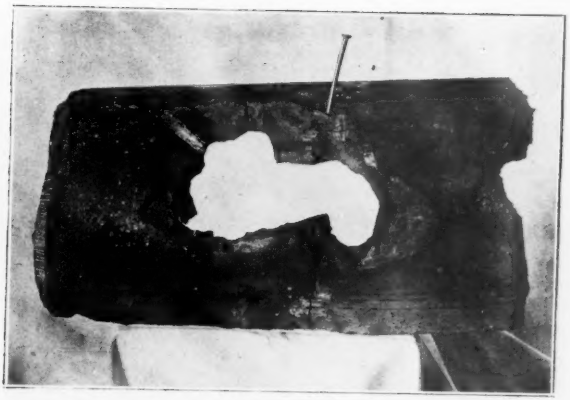

FIG. 1.

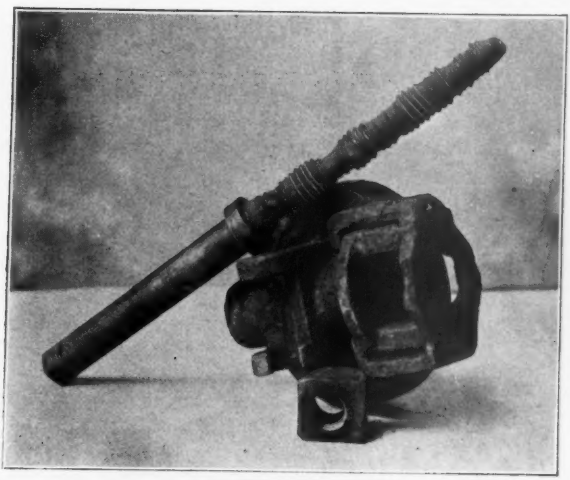

FIG. 2.

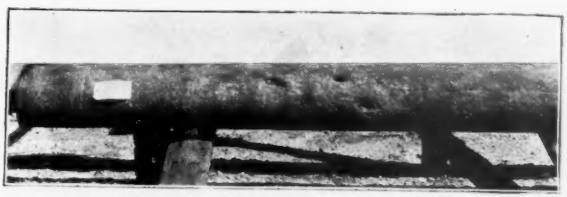

FIG. 3.

Fig. 3. — Eight-inch pipe taken out by Manufacturers' Natural Gas Company in front of power house, West Washington Street, Indianapolis, Ind. In places holes could be punched through the pipe with an umbrella.

Fig. 4. — Service pipe in park, not near street car line, St. Louis, Mo.

PLATE II. *Fig. 1.* — Pipe taken up at St. Louis, Mo. At upper right-hand corner of picture the pipe has been cut with a knife. Also a nail has been driven into the pipe.

Fig. 2. — Four-inch valve destroyed by electrolytic action, not far from power house.

Fig. 3. — Eight-inch pipe removed beyond Belt Railroad, at a point a mile from car line, by Indianapolis Gas Company. The street car tracks cross the pipe line in such a way that a triangle is formed, of which the pipe line forms the base; and this is the direct and shortest route to the power house.

SUPPLEMENT.

On December 22, 1900, Judge Carter of the Superior Court overruled the defendant's demurrer to the complaint in the case of the Manufacturers' Natural Gas Company against the Indianapolis Street Railway Company for $50,000 damages for injuries to the Gas Company's pipes through electrolysis. The court holds that the cause of action is good, and practically asserts that damages will lie. The opinion in part follows: —

"The method in use by the defendant in operating its cars results in serious injury, and, in some cases, to the destruction of plaintiff's pipes. The defendant can, by the use of an approved appliance at reasonable expense, operate its cars so as to avoid injuring the plaintiff's pipes. The plaintiff cannot, by any known method, protect its pipes from injury.

"The plaintiff owns its pipe line laid in the street by legal authority. Such pipe line is property within the meaning of the constitution and laws. It is subject to taxation; it may be sold and purchased as other property. The Street Railway Company seizes on these pipes and makes use of them, as a conductor for its return current, and in so doing greatly injures and, in some instances, wholly destroys them, and this is done under a claim that it is performing a public service under authority of law. Is not this a taking of private

property for public use and for which just compensation must be made?

"I do not see that the fact that the Street Railway Company's tracks, poles, and wires may have been placed in the street before the plaintiff's pipes were so placed can make any difference unless it should be shown that when it placed them there it knew of the injuries to which they would be subjected.

"The city could not and did not grant a monopoly of the street either to the defendant or its predecessor; and when the tracks, poles, and wires were placed in the street, the Railway Company knew that gas and water pipes might be laid in the street at any time, and it acquired its rights to run an electric road subject to that fact, and all the consequences that might follow. The plaintiff is not a trespasser, but occupies the street lawfully, and while there, its property is taken by the Street Railway Company as a consequence of its operations.

"Justice Brown, in the case in 42 Fed. Rep. 279, states that the substance of all the cases which he has examined is that 'where a person is making lawful use of his own property or of a public franchise in such a manner as to occasion injury to another, the question of his liability will depend on the fact whether he has made use of the means which, in the progress of science and improvement, have been shown to be the best.'

"A street railway company is not, however, bound to adopt the latest invention, nor to adopt any before its utility and practicability have been demonstrated by use.

"The case made by the complaint in this cause seems to meet the requirement contained in Judge Brown's statement.

"According to the allegations of the complaint, the defendant has failed to adopt an approved appliance which could be done at a reasonable expense, and when by so doing the injuries complained of could be avoided.

"I cannot see any difference in principle between a case in which liability attaches from a failure to adopt the best-known device, and one where there is a failure to adopt any device whatever, when there are devices by which the injury could be avoided, and the utility of which has passed the point of being a mere experiment.

"These questions are new, and we are without precedent in decided cases for our guidance; but as these new questions arise, the administration of the law should keep step to the new situations arising in

the march of scientific invention and improvement, not by inventing new legal principles, but by the expansion of old and well-recognized principles of law and equity so as to meet and cover the new situation. It would be a reproach to our system of jurisprudence and the administration thereof if a situation could arise in which large and material injury should be done to legal rights and destruction caused to property, and the law be powerless to apply a remedy.

"Take the situation in this city; the number and size of the cars propelled through our streets by electricity is ever rapidly on the increase. Suburban lines are coming into the city from every direction, with cars larger than ever before used on the streets, and the currents of electricity which now are, or soon will be, discharged into the earth of the streets are very large; and if it be true, as claimed in some of the cases which I have examined, that these currents not only attack gas and water pipes, but the steel frames of tall buildings as well, and that such steel frames may be deteriorated and weakened so as to imperil such buildings, is there no remedy in the law to prevent it, or to compel the Street Railway Company to control its return current, when it is conceded that it is reasonably in its power to do so?

"Where a corporation is exercising a public franchise, and does so in such a manner as to cause actual material injury to legal rights and destruction of property, when at reasonable expense, by the adoption of well-known and approved appliances, the injury could be avoided, and the person injured is powerless to prevent or guard against such injury, then I think it must be held to be negligence in the use of its franchise on the part of such corporation not to adopt such approved appliances.

"The destruction of the plaintiff's pipes so as to permit gas to escape and cause destruction to life and property cannot be said to be mere annoyances, inconveniences, or incidental damages. It has been held in New York, in the case of Siebrecht *v.* East River Gas Company (47 N. Y., Supp. 262, 1899), that the Gas Company is liable in damages sustained by the action of gas which escaped from the company's pipes from leaks caused by electrolysis; to be subjected to such a liability cannot be considered a mere incidental damage.

"For the foregoing reasons I think the complaint states a good cause of action, and the demurrer is therefore overruled."

A REPORT ON TRIAL OF 30 000 000 GALLON PUMPING ENGINE AT THE CHESTNUT HILL HIGH-SERVICE STATION OF THE METROPOLITAN WATER WORKS, MADE MAY 1 AND 2, 1900.

BY WILL J. SANDO, RECENTLY SUPERINTENDENT OF PUMPING STATIONS, METROPOLITAN WATER WORKS.

[*Read November 14, 1900.*]

The test was conducted by the engineering department of the Board, represented by Dexter Brackett, engineer of the Distribution Department; Will J. Sando, superintendent of Pumping Stations; and the E. P. Allis Company, represented by Arthur J. West, M.E.

DESCRIPTION OF PLANT.

The engine was designed and built by the E. P. Allis Company, of Milwaukee, Wis. The contract was signed January 1, 1897, and the engine first started in December, 1898. It is of the vertical, triple-expansion, self-contained type, with three single acting outside packed plungers, having at contract speed (about 17½ revolutions per minute) a capacity of 30 000 000 U. S. gallons in twenty-four hours. The pump plungers are placed directly under the steam cylinders and rigidly connected with the steam pistons.

The steam inlet and exhaust valves for the high pressure cylinder and the inlet valves for the intermediate pressure cylinder are of the Corliss type; the exhaust valves for the intermediate pressure cylinder and the inlet and exhaust valves for the low pressure cylinder are of the poppet type. All valves receive their motion from a lay shaft, which is driven from the crank shaft by means of two connecting rods. The cut-off on the high pressure cylinder is controlled by an automatic centrifugal governor and is also adjustable by hand. On the intermediate pressure cylinder the cut-off is adjustable by hand and on the low pressure cylinder the cut-off is fixed.

The cylinders are jacketed on barrels. All valves are placed in the cylinder heads and jacketed only by the working steam.

There are receivers, fitted with copper reheating coils, between the high and intermediate pressure cylinders and the intermediate and low pressure cylinders. The volumes are respectively four and one-half times, and two and three-quarters times, the volumes of the preceding cylinders.

The system of steam distribution through the jackets and receiver coils is as follows: The high pressure jacket is supplied with steam from the main steam pipe at the same pressure as the steam at the throttle valve; the first receiver coil is supplied from the high pressure jacket outlet, and the intermediate pressure jacket is supplied at a reduced pressure from the first receiver coil outlet. There is also discharged into the intermediate pressure jacket the water drained from the first receiver coil inlet, a $\frac{1}{4}$-inch pipe and globe valve being provided for this purpose. From the intermediate pressure jacket the mixture of steam and water enters the second receiver coil, and from here is trapped and discharged into the bottom of the second receiver, and is then trapped to waste. The low pressure jacket is supplied with steam at a reduced pressure from the working side of the first receiver. The connection is taken out at the bottom of the receiver to prevent the water of condensation from entering the intermediate pressure cylinder. To insure circulation in the low pressure jacket there is a $\frac{1}{4}$-inch free pipe connection from the top of the jacket to the working side of the second receiver. The drain from the low pressure jacket is trapped to waste. The drain from the separator is discharged into the top of the first receiver. To keep steam on the low pressure jacket when the engine is not running, a by-pass pipe is provided on the trap which drains the second receiver coil, so that, instead of discharging into the second receiver, the mixture is discharged into the low pressure jacket.

The surface condenser contains 2 000 square feet of cooling surface. The circulating water is taken from and returned to the suction pipe. Directly on top of the condenser there is an exhaust heater which contains 300 square feet of heating surface. The boiler feed pump is attached to and driven by the main engine. The feed water is taken from the out-board circulating pipe on the condenser, and on its way to the pump suction passes through the heater. The air pump and the air compressor for charging the discharge air chambers are attached to and driven by the main engine.

Each pump is composed of five principal castings, which are located at right angles to the longitudinal center line of the engine.

On one side there is a suction valve chamber, and on top of this a suction air chamber. On the opposite side there is a discharge valve chamber, and on top of this a discharge air chamber. The suction and discharge valve chambers are connected by the plunger chamber. The suction, discharge, and plunger chambers rest on and are bolted to a masonry foundation, and the engine bed-plate rests on and is bolted to the top of the suction and discharge air chambers, thus forming a self-contained structure.

The three pumps are connected longitudinally by the suction pipe on one side and the discharge pipe on the other. The pump valves are five eighths of an inch thick and made of the best grade of medium rubber. The valve seats are made of composition, and are mounted, in groups of thirty-five, on cages which can be easily removed from the chambers. The free waterway through each set of suction and discharge valve seats is 121 per cent. of the area of the plunger.

Steam was furnished by a double furnace Belpaire boiler, designed by E. D. Leavitt, M.E., and built by the Lake Erie Boiler Works. Each furnace is equipped with an American mechanical stoker. Forced draft for the stokers is supplied by a Sturtevant blower outfit. The escaping gases pass from the boiler around the tubes of a Green economizer. The feed water is pumped through the tubes of the economizer on its way to the boiler.

METHOD OF CONDUCTING TRIAL.

The contract provided that the engine should perform a duty of 150 000 000 foot pounds for each one thousand pounds of commercially dry steam used by the engine and any auxiliary pumps supplied by the contractor, steam containing less than one and a half per cent. of entrained water, as determined by calorimeter measurement, to be considered as commercially dry steam; the work performed by the engine to be based upon plunger displacement.

As the contract requirement for duty was based upon the quantity of steam used by the engine, great care was taken to accurately determine this amount. All connections between the boiler which supplied steam to the engine and the other boilers in the station were either broken or closed with blank flanges. All condensed steam from the low pressure cylinder was discharged by the air pump into a wrought-iron tank, from which it was drawn into a second

or weighing tank, and from there it was discharged into a third tank, from which the supply for the boiler was taken. Wrought-iron tanks resting on platform scales received the condensed steam from the separator, the jackets of the high and intermediate steam cylinders and receiver coils, and the jacket of the low pressure cylinder. The condensed steam before entering the weighing tanks was passed through coils submerged in cold water, in order to prevent loss from evaporation.

The water from all of these tanks, after being weighed, was discharged into the large suction tank, and was from there forced into the boiler by the feed pump attached to the main engine. The supply to the boiler was regulated by means of the by-pass, through which the discharge from the feed pump could be returned to the suction tank.

During the test all steam used by the stoker cylinders and blowing engine and the economizer engine was supplied by another boiler, so that if there had been no leakage from the boiler, economizer, and piping, the quantity fed into the boiler would have agreed with the quantity received from the engine and separator. In order to determine the amount of leakage from the boiler, economizer, and piping, a test was made on April 28 and 29. For twenty-four hours the steam pressure in the boiler was maintained at 190 pounds, the throttle valve at the engine was closed, and hourly observations were made of the condensed steam from the jackets and separator and of the elevation of the water in the boiler. Sufficient water was pumped into the boiler to bring the water level to the same elevation at the end of the twenty-four hours as it was at the beginning, and it was found that the leakage from the boiler, economizer, and piping was at the rate of 46.35 pounds per hour.

The steam pressure at the engine was determined by means of a mercurial gage connected at the main throttle valve, and readings of this gage were taken every fifteen minutes throughout the trial. The elevation of the water in the pump well was determined from the average of readings of a float gage taken every fifteen minutes during the duration of this test. The pressure of water in the force main was determined from the average of readings taken every five minutes of a carefully calibrated mercurial gage connected with the force main near the discharge from the engine. The revolutions of the engine were observed and recorded every fifteen minutes. The Peabody calorimeter was used for measuring the entrained water in

the steam; four samples were taken during the trial. The steam used by the calorimeter was condensed and weighed in a tank.

Observations were made and recorded each hour during the trial of the steam pressure in the receivers between the steam cylinders, the vacuum in the condenser, the temperatures of steam at the throttle valve and at the inlet and outlet of each steam cylinder, the temperatures of water in the drains from the receiver and the low pressure jacket, the temperature of water discharged from the air pump, of water entering and leaving the condenser and in the several weighing tanks, of air in the engine room, and of the outer air.

In the boiler room a record was made of the weight of coal fed to the hopper of the mechanical stoker during each hour. The level of the water in the boiler, the steam pressure, the draft and the temperature of water entering and leaving the economizer, and of the air in the boiler room were observed and recorded every fifteen minutes. The temperatures of the gases before and after passing the economizer were observed every thirty minutes. A sample of flue gas was taken and analyzed every hour, and gages recording the pressure of air in the ash pit and suction in the flue at end of boiler were read at frequent intervals.

As the contract duty was based upon steam consumption and not upon the amount of coal used, it was not deemed advisable to attempt to begin the test with a new fire under the boiler, or to draw the fire at the close of the trial. Fires were cleaned about two hours before the test began, and once during the twenty-four hours, which is the regular practice in operating the station. The condition of the fires at the beginning and at the end of the test was as nearly the same as could be determined by the careful inspection of three persons; and as the quantity of coal fed to the boiler during the last four hours was above the average during the remaining portion of the time, it is thought that the recorded weight very closely represents the actual quantity burned during the twenty-four hours.

All scales for weighing water and coal were tested and sealed by the city sealer of weights and measures immediately before the trial. All indicator springs were tested a few days before the trial. All thermometers were tested. All pump valves were tested for leakage and found to be practically tight.

Indicator diagrams from all the steam cylinders and pumps were taken every hour. All the indicators, six on the steam cylinders (one on either end), and three on the pumps, were electrically connected in

such a manner that nine diagrams were taken simultaneously, each of which represented the average pressure in the cylinder or pump for one minute. The pencil friction of the indicator was obviated by a current breaker, which gave the pencil an intermittent instead of constant contact, and formed the card by a series of dots. As the pencil went over each card 17.54 times the appearance is almost a continuous line. While the indicator diagrams were being taken, five-second observations were made of the pressure in the force main.

The average friction of the engine for the twenty-four hours of the trial was determined from the average of the differences between indicated horse-power and the actual work done during times while the diagrams were being taken.

The coal used during the trial was the Loyal Hanna, Sonman Shaft, run of the mine coal, in regular use at the station. The coal was tested for its calorific power, and the thermal units given in table represent the value of one pound as actually used.

GENERAL DATA.

Principal Dimensions of Engine.

1.	Diameter H. P. cylinder (nominal)	30 in.
2.	Diameter I. P. cylinder (nominal)	56 in.
3.	Diameter L. P. cylinder (nominal)	87 in.
4.	Cylinder clearances:	
5.	High pressure	1.35 per cent.
6.	Intermediate pressure	0.55 per cent.
7.	Low pressure	0.45 per cent.
8.	Diameter of plungers (nominal)	42 in.
9.	Stroke of pistons and plungers (nominal)	66 in.
10.	Diameter suction and discharge pipes	48 in.
11.	Diameter fly wheels (2)	20 ft.
12.	Weight of each wheel	50 000 lbs.
13.	Revolutions per minute for capacity	17.5
14.	Speed per minute	192.5 ft.
15.	Diameter of crank shaft journals	18 in.
16.	Length of crank shaft journals	24 in.
17.	Angle of cranks	120°
18.	Diameter H. P. and L. P. crank pins	9 in.
19.	Length H. P. and L. P. crank pins	11 in.
20.	Diameter I. P. crank pin	14 in.
21.	Length I. P. crank pin	11 in.

Principal Dimensions of Boiler Plant.

22. Boiler diameter	90 in.
23. Boiler length (over all)	34 ft. 4 in.
24. Number of tubes	201
25. Diameter of tubes	3 in.
26. Length of tubes	16 ft.
27. Heating surface	2 849 sq. ft.
28. Inside area of tubes	8.49 sq. ft.
29. *Grate, length (each)	7 ft.
30. *Grate, width (each)	4 ft. 6.75 in.
31. Grate, area (2 furnaces)	63.875 sq. ft.
32. Ratio of heating to grate surface	44.6 to 1
33. Ratio of grate to inside area of tubes	7.52 to 1
34. Economizer heating surface outside of tubes	1 680 sq. ft.
35. Height of stack	150 ft.
36. Inside diameter of stack	5.5 ft.

Measured and Calculated Dimensions.

	High Pressure.		Intermediate.		Low Pressure.	
	Top.	Bottom.	Top.	Bottom.	Top.	Bottom.
37. Diameter steam cylinders measured at shops	30.005	30.005	55.984	55.984	87.009	87.009
38. Diameter steam cylinders at temperature due to actual working conditions (calculated), inches	30.05	30.05	56.04	56.04	87.07	87.07
39. Area steam pistons under working conditions, square inches	709.22	675.62	2466.53	2432.93	5954.26	5920.66
40. Scale of steam indicator springs	119.80	118.70	19.60	19.65	9.64	9.78

	High Pressure.	Intermediate.	Low Pressure.
41. Stroke of pistons and plungers, engine running, inches	66.000	65.9375	65.96875
42. Stroke of pistons and plungers, engine running, feet	5.500	5.4948	5.4974
43. Circumference of plungers, feet	11.004	11.0025	11.0010
44. Diameter of plungers, feet	3.5027	3.5022	3.5017
45. Area of plungers, square feet	9.63588	9.63325	9.6306

* American mechanical stokers used under boilers with forced draft.

	High Pressure.	Intermediate.	Low Pressure.
46. Area of plungers, square inches	1 387.5667	1 387.1880	1 386.8064
47. Displacement of one plunger per revolution (water 62.4 lbs. per cubic foot), cubic feet	52.9973	52.9328	52.9433
48. Number of steam piston rods	2.	2.	2.
49. Diameter of steam piston rods, inches	4.625	4.625	4.625

TRIAL DATA.

50. Date of trial .....9.15 A.M., May 1, to 9.15 A.M., May 2, 1900.
51. Duration of trial .....24 hours.

Average Pressures.

52. Steam at boiler .....187.37 lbs. per sq. in.
53. Steam at throttle .....185.47 lbs. per sq. in.
54. First receiver .....30.85 lbs. per sq. in.
55. Second receiver .....−3.31 lbs. per sq. in.
56. Vacuum .....13.80 lbs. per sq. in.
57. Vacuum .....28.16 in. mercury.
58. Barometer .....14.63 lbs. per sq. in.
59. Barometer .....29.85 in. mercury.
60. H. P. jacket .....185.47 lbs. per sq. in.
61. I. P. jacket .....73.40 lbs. per sq. in.
62. L. P. jacket .....4.80 lbs. per sq. in.
63. Draft in ash pit .....1.38 in. water.
64. Draft in flue at end of boiler .....0.47 in. water.

Average Temperatures.

65. Steam at boiler .....382.95° F.
66. Steam at throttle .....382.15° F.
67. Steam entering H. P. cylinder .....381.34° F.
68. Steam entering first receiver .....275.05° F.
69. Steam entering I. P. cylinder .....278.36° F.
70. Steam entering second receiver .....199.46° F.
71. Steam entering L. P. cylinder .....198.91° F.
72. Steam leaving L. P. cylinder .....116.41° F.
73. Water from second receiver .....197.45° F.
74. Water from L. P. jacket .....205.07° F.
75. Water discharged from air pump .....76.19° F.
76. Water in condenser tank .....76.19° F.

77. Water in second receiver tank.....90.44° F.
78. Water in L. P. jacket tank .....83.88° F.
79. Water in separator tank .....60.94° F.
80. Water in make-up tank .....52.67° F.
81. Water entering economizer.....79.72° F.
82. Water leaving economizer (fed to boiler).....154.98° F.
83. Water condenser circulating inlet (water pumped).....52.67° F.
84. Water condenser circulating outlet .....78.79° F.
85. External air.....51.95° F.
86. Engine room .....66.50° F.
87. Boiler room .....83.40° F.
88. Flue gases leaving boiler.....485.40° F.
89. Flue gases leaving economizer .....221.90° F.

Data for Head Pumped Against.

90. Average elevation of water in force main above Boston City Base ..... 271.856 ft.
91. Average elevation of water in wet well above Boston City Base ..... 131.506 ft.
92. Average net head pumped against ..... 140.350 ft.

Revolutions.

93. Total revolutions during 24 hours..... .....25 539.
94. Average revolutions per minute.....17.7354

Useful Work Performed by Engine.

95. Water pumped per revolution (plunger displacement) ..... 1 188.454 U. S. gals.
96. Water pumped per revolution (plunger displacement) ..... 158.8732 cu. ft.
97. Water pumped per revolution (at 62.4 lbs. per cubic foot) ..... 9 913.7 lbs.
98. Total plunger displacement..... 30 351 926 U. S. gals.
99. Plunger leakage ..... 38 015 U. S. gals.
100. Plunger leakage ..... 317 110 lbs.
101. Water pumped (no allowance for slip)..... 30 313 911 U. S. gals.
102. Net foot-pounds useful work (plunger displacement) ..... 35 534 608 420 ft. lbs.
103. Net foot-pounds useful work deducting plunger leakage..... 35 490 102 245 ft. lbs.

Water Fed to Boiler.

104. To suction tank from condenser tank.....169 819.0 lbs.
105. To suction tank from L. P. jacket tank .....25 356.5 lbs.
106. To suction tank from second receiver tank.....5 81.5 lbs.

107. To suction tank from separator tank ..... 1 933.5 lbs.
108. To suction tank from make-up tank ..... 3 115.5 lbs.
109. Add for suction tank low at end of test ..... 10.0 lbs.
110. Add for boiler level low at end of test ..... 54.0 lbs.
111. Total water fed to boiler ..... 205 370.0 lbs.

Steam Out of Boiler not used by Engine.

112. Water from separator ..... 2 019.0 lbs.
113. Steam blown through calorimeter (weighed in tank) ..... 649.0 lbs.
114. Leakage from whole plant exclusive of engine ..... 1 112.5 lbs.
115. Total steam out of boiler not used by engine ..... 3 780.5 lbs.
116. Steam chargeable to engine ..... 201 589.5 lbs.

Steam Received from Engine.

117. From condenser ..... 170 427.0 lbs.
118. From L. P. jacket ..... 25 886.5 lbs.
119. From second receiver ..... 5 276.0 lbs.
120. Total steam used by engine ..... 201 589.5 lbs.
121. Average entrainment in steam entering engine, 1.37 per cent. ..... 2 761.8 lbs.
122. Total dry steam used by engine ..... 198 827.7 lbs.
123. Percentage of total steam used in jackets ..... 15.45 p. c.

British Thermal Units.

124. Heat of vaporization steam, 200.10 absolute, equals. 843.77 B. T. U.
125. Heat of liquid steam, 200.10 absolute, equals ..... 354.64 B. T. U.
126. Heat of liquid discharged from condenser, temperature 76.19° F., equals ..... 44.30 B. T. U.
127. Heat of liquid discharged from second receiver, temperature 197.45° F., equals ..... 166.15 B. T. U.
128. Heat of liquid discharged from L. P. jacket, temperature 205.07° F., equals ..... 173.77 B. T. U.
129. Heat of vaporization steam at boiler, 202 lbs. absolute, equals ..... 843.20 B. T. U.
130. Heat of liquid steam at boiler, 202 lbs. absolute, equals ..... 355.40 B. T. U.
131. Heat of liquid entering economizer, temperature 79.72° F., equals ..... 47.81 B. T. U.
132. Heat of liquid entering boiler, temperature 154.98° F., equals ..... 123.26 B. T. U.
133. Heat per pound of moist steam used in cylinder equals 1 142.55 B. T. U.
134. Heat per pound of moist steam used in H. P. and I. P. jackets and receiver coils, discharged from second receiver, equals ..... 1 020.70 B. T. U.
135. Heat per pound of moist steam discharged from L. P. jacket equals ..... 1 013.08 B. T. U.
136. Heat put into feed water by economizer equals ..... 75.47 B. T. U.

137. Heat put into steam by boiler equals ..... 1 075.32 B. T. U.
138. Heat to convert condenser water to steam equals ....
194 721 400 B. T. U.
139. Heat to convert L. P. jacket water to steam equals ..
26 225 100 B. T. U.
140. Heat to convert second receiver water to steam equals
5 385 200 B T. U.
141. Total heat used by engine .....
226 331 700 B. T. U.
142. Heat contained in one pound of wet coal ..... 14 023 B. T. U.

Horse-Power Figures.

143. Average percentage of friction of engine (average of 18 sets of cards)	6.71 p. c.
144. Average delivered horse-power (useful work)	747.785
145. Average Ind. horse-power, H. P. cylinder	292.057
146. Average Ind. horse-power, I. P. cylinder	248.773
147. Average Ind. horse-power, L. P. cylinder	260.739
148. Total Ind. horse-power	801.569
149. Average moist steam per I. H. P. per hour	10.479 lbs.
150. Average dry steam per I. H. P. per hour	10.335 lbs.
151. Average B. T. U. per I. H. P. per minute	196.080

Coal and Rate of Combustion and Evaporation.

152. Total coal burned 24 hours	19 612 lbs.
153. Coal burned per square foot of grate surface per hour	12.793 lbs.
154. Coal burned per square foot of heating surface per hour	0.287 lbs.
155. Evaporation per pound of coal, actual conditions, including economizer	10.472 lbs.
156. Evaporation per pound of coal, actual conditions, excluding economizer	9.785 lbs.
157. Evaporation per pound of coal, from and at 212° F., including economizer	12.478 lbs.
158. Evaporation per pound of coal, from and at 212° excluding economizer	11.660 lbs.
159. Evaporation per square foot of heating surface per hour	3.00 lbs.
160. Coal per I. H. P. per hour	1.02 lbs.
161. Coal per D. H. P. per hour	1.09 lbs.
162. Coal burned 24 hours, for fan, stoker, and economizer engines, as determined by subsequent test	800 lbs.
163. Total coal burned if boiler supplying steam for test had supplied steam to fan, stoker, and economizer engines	20 412 lbs.

164. Kind of coal, Loyal Hanna, Sonman Shaft.

Duties.

165.	Duty per 1 000 lbs. moist steam, deducting plunger leakage (contract basis)	176 051 500 ft. lbs.
166.	Duty per 1 000 lbs. dry steam, deducting plunger leakage	178 497 000 ft. lbs.
167.	Duty per 1 000 000 B. T. U.	157 002 500 ft. lbs.
168.	Duty per 100 lbs. coal, making allowance for coal required for supplying steam to fan, stoker, and economizer engines	173 869 000 ft. lbs.

Efficiencies.

169.	Efficiency of mechanism	93.29 p. c.
170.	Efficiency of boiler and economizer, actual	85.9 p. c.
171.	Efficiency of boiler alone, actual, if economizer had not been used	80.3 p. c.
172.	Thermal efficiency of engine	21.63 p. c.

DISCUSSION.

MR. R. J. FLINN.* I would like to inquire, in relation to the method of disposing of the jacket water, which seems to be something entirely new, who claims to be the originator of the device. Perhaps Mr. Brackett can tell us.

MR. DEXTER BRACKETT.† So far as I know, the device was originated by the Allis Company, and I think by Mr. West, their mechanical engineer.

MR. FLINN. Then I would state that this was published by me several years ago in the New York *Power* and also in the *American Machinist*, and in some of the English and French papers. I first used it, and I sent the drawings to Mr. Reynolds of the Allis Company, and I think probably Mr. West got the idea from that.

MR. BRACKETT. That part of it I know nothing about.

MR. FLINN. If anybody wishes to see it, it is published in the June, 1897, *Power*, on page 20; also in the *English Mechanic* of a later date, the *American Machinist*, and some of the French mechanical papers published about that time.

* Engineer, Brookline Water Works.
† Engineer, Distribution Department, Metropolitan Water Works.

CAUSE AND EFFECT OF ELECTROLYTIC ACTION UPON UNDERGROUND PIPING SYSTEMS.

BY A. A. KNUDSON, ELECTRICAL ENGINEER, NEW YORK CITY.

[*Read December 12, 1900.*]

Your President having honored me with an invitation to read a paper before you pertaining to electrolysis, we have thought, in view of what is now generally known on the subject, that such a paper, to be of interest, should deal with the latest discoveries in the state of the art, which refer to the cause and effect of straying railway currents upon water mains, gas mains, or other underground structures.

We have therefore gleaned a few incidents and facts which have come under our personal notice in a number of recent investigations, which we will present, in the hope that they may be of some value, and additional light may be thrown on this important subject.

With a view of treating the subject with some degree of system, we shall consider it under the following heads; namely: —

1. Cause of deflection of currents from well-bonded tracks to water mains.
2. Acute points of deflection of currents to water mains.
3. Effect of joint resistance on water mains.
4. Effect upon water mains in a positive district.

It will be understood that in this paper "negative" districts are where the general tendency of the electric current is to enter the water mains; and "positive" districts are where the general tendency of the electric current is to leave the water mains; the damage occurring under the positive condition.

Under the first heading, namely: —

1. *Cause of deflection of currents from well-bonded tracks to water mains.*

Where the rails are used for the return current, as is the case in the single wire trolley systems, they must of necessity be in contact with the earth, which has more or less moisture; in the same earth a short distance away are located water mains and other structures;

this intervening earth is the connecting link between the railway tracks and water-piping systems, through which current passes from one to the other. It is not surprising, therefore, that the interlacing network of the piping system of a city under such conditions should offer a good electrical return for the railway current, even when the rails are most perfectly bonded. It often happens, where there are large mains under the streets, that they constitute electrical conductors whose area of cross section far exceeds the cross section of the rails; in such case, even if the rails were electrically welded, or cast welded, there would still be more or less deflection of current to the mains. We have noticed this where we have made tests in the neighboring cities of Providence, R. I., and Pawtucket, R. I. On a line in Providence, so welded, the readings ranged from 4 to 8 volts negative, and in Pawtucket, from 0.5 positive to 4.4 volts negative. I presume the cast weld joint, when well placed, makes as good an electrical contact between the rail ends as any of the specially contrived bonds; but none of them, not even a continuously solid rail, can entirely confine the currents to the rails. We have made many tests at rail joints, and have found in the case of many well-bonded rails a difference of potential of not over 0.003 volt. This is coming closely to the conductivity of the rail itself, and if such a condition could be continuously maintained in all parts of a railway system, the rapid destruction of water mains by electrolysis would be materially reduced. Such a condition, however, I believe to be practically impossible. In the investigations of some fourteen different cities, some of which have the best modern construction of electric railways, using the rails as a return, I have found quite high differences of potential between rails and mains at different places, and electrolytic damage upon the pipes in many cases, where uncovered.

A well-bonded track return, therefore, should not be accepted as a cure for electrolysis.

2. *Acute points of deflection of currents to mains.*

These inevitably result from the use of the "rail return." Such points here and there in a city generally go unnoticed until the effect is shown in the bursting of service pipes or mains caused by electrolysis, or until some one has been called in to investigate. The high differences of potential which generally cause such acute deflection are often due to broken or worthless rail bonds at switches and crossings. These are found in every city, more or less. Sometimes we find other causes for these escapes, as, for instance, in one case

where new rails had been placed on a line, a few old rails were left at the terminus; the result, a difference of potential of 42 volts; where the new rails left off and the old commenced, a high reverse (positive) reading.

I have found differences of potential at the joints of rails ranging from tenths of a volt as high as 25 volts. Such conditions mean practically "open circuit" in the rail return, and generally corresponding damage *somewhere* to the water mains by electrolysis.

One exaggerated cause of current deflection to the water mains is the use of rail chairs in track construction, of which there are still many in existence in various cities at the present day. Examples of these were found in three cities where I have investigated; namely, Peoria, Ill.; Reading, Pa., and Pawtucket, R. I. On some of the lines in those cities the chairs have since been removed. In every case, on lines so constructed, the voltmeter showed high readings. This is largely attributed to their being placed necessarily deep in the ground and to the large amount of surface contact which they present to the earth.

Plate I, Fig. 1, shows some chairs which have been removed from street railway track. It will be seen that the two flanges or legs which are spiked to the ties at their base are in contact with the moist earth both outside and inside when in place, making a convenient outlet for the current from the rails to earth and water mains.

This picture has been shown before in the excellent paper on electrolysis delivered by Mr. D. H. Maury at the convention of the American Water Works Association, held at Richmond, Va., last May, but we show it here as an illustration of one cause of current leaving the rails; the chair at the left, you will notice, has been so reduced by electrolytic action at its base that its original shape is entirely changed, as will be seen by comparison with the one on the right, which is not so damaged.

Fig. 1 is a view of a steam railroad grade crossing, on the line of the Reading & South Western (electric) Railway, at Reading, Pa. This is another illustration of exaggerated deflection of current from rails to water mains; this drawing, which was prepared from photographs (with the exception of the pipe, which is shown for illustration), shows not only the exact construction of the crossing, but the direction of current into and out of the water main, at each side of the crossing.

The voltmeter survey showed that the water main was negative to

the rails through the street in which the cars passed, and as high as 9 volts at the east side of this crossing, and positive on the west side to 6.5 volts. Suspecting that the cause of the jump into and out of the pipe in that short distance was defective bonding on the crossing, we made tests there, and found that scarcely one of the short pieces of rails of the trolley tracks had any electrical connection with another. In a number of tests made between the ends of these parts of rails with the voltmeter, the lowest reading was 4 volts, and the highest 25 volts; the high differences of potential, however, being due to the movements of the cars; but they all showed the condition of *open circuit* in the rail return.

In making tests near and in front of the power station, which was about one thousand feet further west of this crossing, we were struck with the high readings, which ranged from 8 to 26 volts positive. We have often noticed before this that where such high differences of potential are found there is generally a bad break somewhere in the rail return, which can be found if carefully looked for; in this case, we were looking for just such an opening in the tracks, but did not expect to find it on a steam railroad crossing, as previously, where we have made tests on steam track crossings, they have been found in fairly good order.

You will notice in this case the water main acts as a bridge to carry the trolley current past the break in the rails; the current returns again to the rails after passing the break. This is strictly in accordance with electrical action, where two paths are offered for

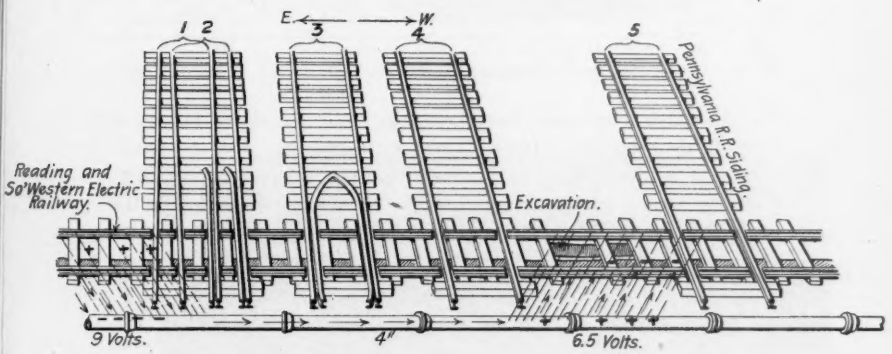

FIG. 1. — CONDITIONS ON CHESTNUT STREET NEAR POWER HOUSE, READING, PA.

the current; if one fails, the other will assume its load, if of sufficient conductive capacity.

The next picture, photograph No. 3 (Plate II, Fig. 1), shows the condition of the water main at the excavation just beyond this crossing. The hole at the left in this piece of pipe is where the pipe burst when we were trying to find how deep in the cast iron the soft graphite — effect of electrolysis — extended; we soon found that it extended entirely through the pipe at this place, and also at another place at the other end of this piece of pipe, while at other places it was badly damaged.

In this particular case where the *cause* is shown of current deflection to the water main, its return to the rails, and the consequent destruction of the pipe, there appears to be no link in the chain missing, from *cause* to *effect*.

There is another point to be considered, where an open circuit in

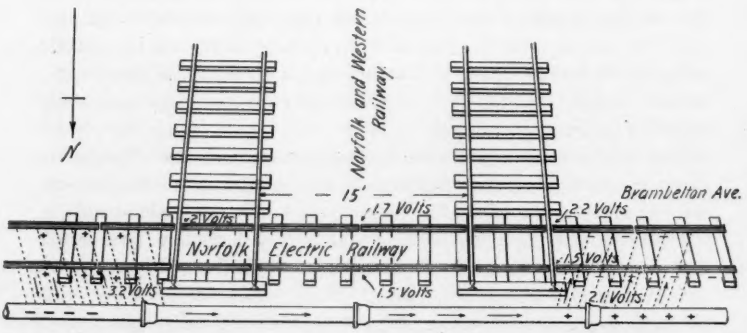

FIG. 2. — CROSSING OF ELECTRIC AND STEAM RAILROADS, NORFOLK, VA.

the rails exists over steam track crossings; and that is the danger of a trolley car becoming "stalled" over such crossings and the possibility of a bad accident. This is possible, particularly in dry weather, when the tracks on the crossing would have little contact with the earth; and this may have been the cause of some accidents which have happened in the past on steam railroad crossings, where trolley cars have been run down.

To show that these conditions found on the crossing in Reading are not exceptional, we show in Fig. 2 a view of another one, found at Norfolk, Va. In this case you will notice there are five openings

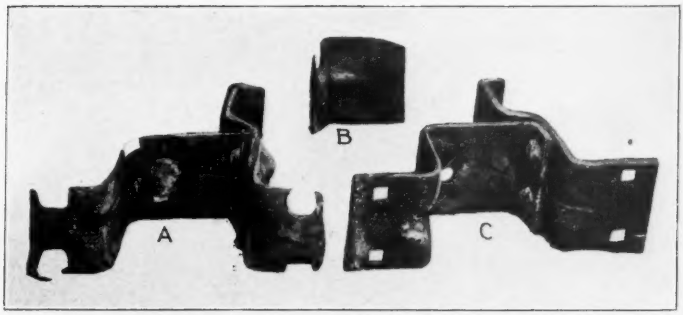

FIG. 1. — RAIL CHAIRS REMOVED FROM STREET RAILWAY TRACK.

FIG 2. — EFFECTS OF ELECTROLYSIS ON BELL OF 6-INCH PIPE, PROVIDENCE, R. I.

FIG. 3. — DESTRUCTION OF WATER PIPE BY ELECTROLYSIS, PROVIDENCE, R. I.

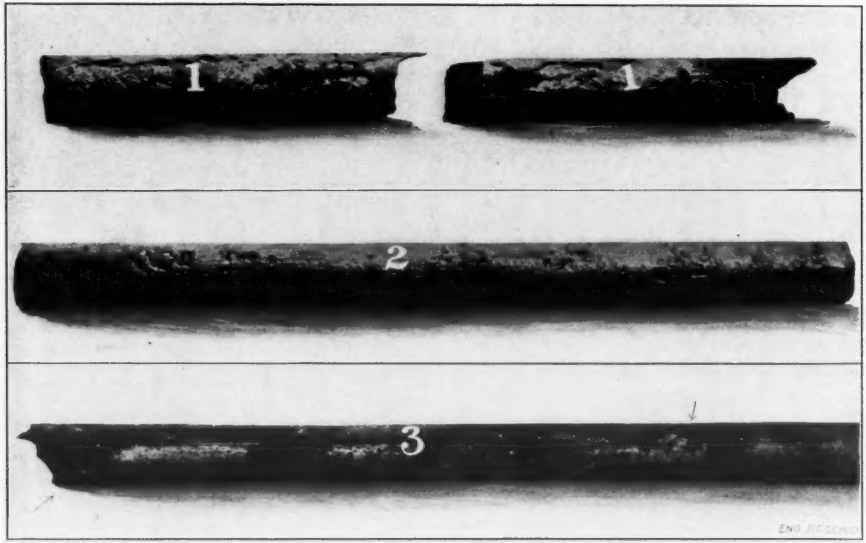

FIG. 1. — WATER MAINS TAKEN UP NEAR RAILROAD CROSSING, READING, PA.

between the rails according to the voltmeter, the readings of which are shown at each place where taken; three on one side of the track and two on the other. These openings cause the current, as in the former case at Reading, to pass down to the water main from the rails at one side of the crossing and up again from the main to the rails on the other side, creating a condition destructive to the water mains.

Both of these crossings, the one in Reading and the other in Norfolk, show plainly that such conditions can exist for a long period of time unknown to either the city authorities, the steam railroad companies, or even the electric railway company in any city in this country, and are not only ruinous to the water mains, but a menace to public safety.*

3. *Effect of joint resistance on water mains.*

This part of the subject we think is fully as important as any other, for the reason that it affects a larger area in the piping system of a city; and although of slower action than the more noticeable effects found in the positive districts, it is important as showing that the mains are being aged and damaged, while being put to a use entirely foreign to what they were intended for. The shunting of the current around the joints, either through the moist earth on the outside or through the water on the inside, owing to the resistance of the joint, is the cause of pitting or softening of the metal on the high potential side. We find evidence of the current shunting the joints of pipes more or less in every city where we investigate; the following views will illustrate this joint action clearly.

Plate I, Fig. 2, is from a photograph of a piece of six-inch pipe removed from a street in Providence, R. I., and shows the action of electrolysis, both upon the outside and inside; this we think is a good illustration of the action of the shunting current. Several of the outside indentations on the rim of this bell, and also at many other bell ends of pipe which were taken up in this street, showed the presence of graphite, — a sure evidence of electrolysis under such conditions. The inside corners of this and several other pieces were easily shaved down to a depth varying from one eighth to three sixteenths of an inch, as shown in the picture.†

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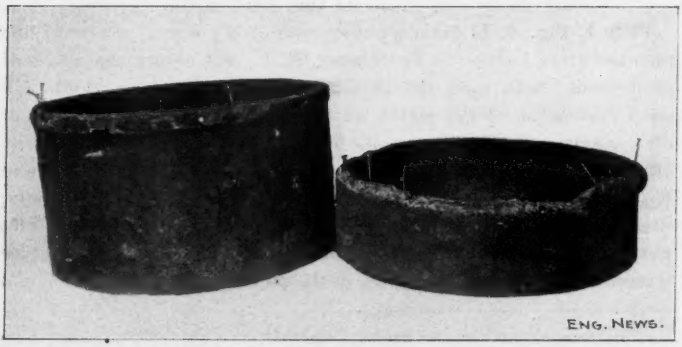
* I am informed that these two crossings have been put in good order since the reports were made.

† Since this paper was presented to the New England Water Works Association a striking example of the effect of joint resistance has been published on pages 66 and 67 of *Engi-*

neering News of January 24, 1901, by Mr. D. H. Maury, consulting engineer, with cuts, which are reproduced herewith. He says:—

"Within the last year the writer has never failed to find some evidences of electrolytic action on the mains in Peoria wherever their joints have been examined by him, no matter whether in the positive or negative district. The photographs, Figs. 3 and 4, show examples of pitting in 16-in. pipes which were removed in the spring of 1900. There were in all nearly 1 000 feet of this pipe, which was about two miles from the power station, and ran off at right angles to the tracks. It was always negative to the rails, and the current flowed along it from the spigot end of one pipe into the bell end of the next. No pits could be found anywhere on this pipe except near the positive side of each joint, but the spigot end of every single pipe was pitted, either on the inside or outside or both, where the current left it.

"These photographs furnish another striking instance of electrolytic pitting in the negative district, and show the danger to which an entire piping system is exposed when current is allowed to flow along the mains, a condition that cannot be avoided if the single trolley system is continued."



FIGS. 3 AND 4.—VIEWS SHOWING ELECTROLYTIC PITTING ON PIPES OF PEORIA WATER CO.

4. *Effect upon water mains in a positive district.*

I presume that all present have seen in one form or another the destructive effect of electrolysis upon water mains and service pipes, and very likely have experienced such damage to the property in their charge.

We shall not take up the time, therefore, in showing a large number of pictures of cast-iron pipe destroyed by electrolysis, but will show three, each one having some special reference.

No. 1 of Plate II, Fig. 1, shows sections of pipe taken up at Reading near the power station of the Reading & South Western Railway Company; these were removed previous to the investigation, and perhaps were an incentive to our being called there. The destruction of this pipe, as you will note, is complete.

No. 2 of the same figure is interesting from the fact that this piece of pipe had only been down about one year; it is apparent from the photograph that it was nearly destroyed, and shows what short work electrolysis will make of cast-iron pipe when the conditions are favorable.

Plate I, Fig. 3, is from a photograph of pipe taken from Traverse Street, Providence, in October last, and shows a complete case of electrolytic destruction. Mr. Otis F. Clapp, the city engineer, who kindly furnished this photograph, says that he had two other excavations made about twenty-five feet each side of where this pipe was taken out, but found nothing serious in the way of damage; this goes to show that it is not always possible to accurately locate the points where the most damage is occurring. Sometimes it is discovered at the first attempt, and then again not until the second or third, and perhaps not at all at the precise openings made.

Usually the principal positive districts in a city are in the vicinity of the power stations, but it often occurs that for various reasons positive conditions are found in negative districts.

One or two cases in point may be mentioned: In Reading, Pa., a pipe was uncovered where the voltmeter readings between hydrant and rails were but 0.7 of a volt negative. We found electrolytic pittings ranging from one eighth to one fourth of an inch in depth scattered all over the upper surface of the pipe; and on further investigation it appeared that the pipe at this point *had been positive* to the rails before the change to new track was made, and the positive condition was now reversed to a negative by the change at this point, and the trouble shifted to another point further down the line, where a high positive reading was found.

Let us take another case: At Norfolk, Va., there was a trestle about one thousand feet long over a marsh, upon which the electric cars ran. Near one end of this trestle the voltmeter readings were positive, amounting to upwards of four volts. An excavation revealed the fact of one large indentation or pitting filled with graphite on the rim of a bell, nearly one half an inch in depth and about three fourths of an inch in diameter; other pittings to a lesser degree were also found at other places on this pipe. In looking about for a cause for this positive effect in a negative district, we examined the rails over the trestle and found only six bonds, by actual count, the balance having strayed or been stolen.*

Many similar cases could be related which we have met in our experience, but we think this point of positive conditions in a negative district will be fairly well understood. It will be seen from all this that railway current, after leaving the rails for the water or gas mains, is entirely *out of control*, and will roam throughout the piping systems of a city, causing damage at unknown places, as well as at points discovered through the bursting of pipes or through investigation.

A current having once entered the piping systems of a city is just as much beyond control as a runaway horse; both may be responsible for loss of life as well as damage to property.

These straying currents often take peculiar paths in selecting their routes back to the power stations.

In New York we find currents straying over the Brooklyn Bridge, some going north through the piping system of Manhattan, crossing the East River back to the power station in Brooklyn; other currents go south towards the Battery, and take the river bed or cables to the South Brooklyn power station. In Providence we find them taking a short cut from the positive district on the east side of the Providence River across that river to the power station on the west side. In Pawtucket they find their way into the Blackstone River and follow that stream to the power station. And it is not surprising that the various underground piping systems should act as returns for the current in place of the rails. Let us consider for a moment what sort of a conductor the rails of a track make. We find in a mile of single track of 30-foot rails, 352 joints; counting switches and crossings, there would easily be 400 joints to the mile, or one

* Since the Norfolk report was made, the rails on this trestle have been newly bonded, and a re-survey shows the conditions much improved.

joint to about every thirteen feet; if this so-called conductor were in the shape of a wire placed on poles, its removal would be compelled through ridicule alone, if through no other cause. These 400 joints which are covered up in the ground are continually subject to corrosive action, impairment of electrical contact by traffic over the rails, and breakage of bonds; and consequently a continual increase of resistance is going on, which means a corresponding increase of flow of current towards and through the piping systems. The escape of current to water and gas mains would be bad enough if the rails were continuously perfect conductors; as a matter of fact they are not, and a continuously perfect conductor in a rail return is practically impossible, owing to the conditions stated. Rail bonds *will* become corroded and broken in course of time, in many parts of the system; and on most electric railways such breaks will long go unnoticed.

Partial relief may be obtained at acute points by careful attention to the track returns; but it is apparent that the injury to water mains will continue so long as one side of the railway circuit is in contact with the earth, and any part of the current can find its way into the water pipes.

A complete metallic circuit entirely insulated from the earth is the only real remedy; such a system has been in successful operation for years, overhead or underground, in Cincinnati, New York, Washington, and the District of Columbia. Nothing stands in the way of its general adoption except the hostility of the electric railway companies and their political influence in municipal affairs.

City ordinances designed for the purpose of protecting the water mains are often liable, if care is not used, to place a municipality in an unfortunate position in this respect, from the fact that they may be led to accept some scheme intended as a cure or partial cure for electrolysis; the effect of such ordinances may be to relieve the railway company from liability for future damage, and to throw the responsibility of the cost for any further changes upon the city itself.

It may be known to most of you that damage by electrolysis to water mains throughout the country is on the increase; almost every day we learn of new cases; even those places that six months or a year ago were feeling easy are now quite anxious. One case in point: A water-works superintendent last summer assured me that in his city they had no trouble from electrolysis and did not expect

any. A few days ago the same gentleman was an "anxious inquirer" as to the cost of an investigation. The "trouble" had appeared. In view, therefore, of the accumulating instances of pipes ruined by electrolysis, it is not strange that you water-works people are not feeling quite happy under the surface.

In conclusion, we believe sufficient has been said as to the cause and effect of electrolysis on water mains to place the matter fairly before you, and we will now review briefly some of the points which have been touched upon.

In well-bonded and well-watched track systems, where there is a liberal use of copper for track feeders, differences of potential may be fairly low, and acute points fewer and less aggravated. But it is a very serious thing that even then, millions of dollars' worth of pipe may be having their life shortened by the slower and more widely distributed process of electrolysis, caused by the milder currents, the result of which will have to be reckoned with in the future. The difference is merely one of time.

As to acute escapes, it is these that are mostly responsible for the ruined pipes so frequently found, and which indicate the wider and more serious destruction.

A case in point of acute action is illustrated by the photograph of a piece of pipe, which was shown on the screen, taken from Reading, Pa., shown in Plate II, Fig. 1, and marked "2." This, as has been stated, had only been down about one year, and was shown to be nearly ruined.

Referring to actual breaks in the rail return over steam railroad crossings, the views showing the cause — and a ruined pipe showing the effect — leave but little to add to this part of the subject, except to say we believe it of such importance as to deserve the attention of either State or city authorities; for it seems, in some cases at least, that electric railway companies cannot be depended upon to continually preserve intact the electrical continuity of their rails over steam track crossings.

This point should, we believe, be just as carefully protected by law as the speed of trolley cars is now regulated in most cities by city ordinances.

The joint resistance in water mains, and the consequent damaging effect when current is passing upon the high potential side, is now pretty well known; engineers and others, who once favored the method of connecting water mains to the rail returns in a positive

district for the purpose of lessening the injury to pipes by electrolysis at such points, have now generally abandoned that plan, as it is found that more current is invited upon the pipes with resulting damage at or near the joints.

The effect upon water mains in the positive district is too well known to dwell upon, but one point may be referred to, and that is, while it is usually located in the vicinity of a power station, this is not an exclusive location. In a city recently examined we found four different points, widely separated from each other and from the power station, in negative districts, where the mains were positive to the rails, and the current was gnawing at the water mains silently and undisturbed, as the unseen worm gnaws at the roots of trees.

In view, therefore, of the apparent impossibility of preventing railway currents from straying, more or less, into the pipes, under the present single trolley system, resulting in their injury and destruction, we believe we are justified in requiring a method entirely insulated from the earth, before an actual remedy from electrolysis is found.

We are aware that it will entail more or less expense upon railway companies in making such a change, and we are also aware that they will derive a benefit in increased economy in operating, which should mean a corresponding increase in dividends; hence there should be no great opposition on the part of the railway companies to making such a change.

These are some of the incidents and impressions met with in making electrolytic investigations. If our exposition of the *cause and effect* of such incidents has thrown further light on the subject, or has proved of interest to you, we shall feel that the object of this paper has been attained.

DISCUSSION.

THE PRESIDENT. We expected to have with us Mr. Woodbridge, of the General Electric Company, to discuss Mr. Knudson's paper, but he is not here, and I will call upon Mr. Brackett to open the discussion.

MR. DEXTER BRACKETT.* I did not come here at all prepared to say anything, Mr. President; I rather came to listen and to learn. It seems to me that, so far as our present knowledge of this subject goes, we are very well aware that the water pipes are suffering to a

*Engineer, Distribution Department, Metropolitan Water Works, Boston, Mass.

greater or less extent from electrolytic action, and I think what we all want to know now is the remedy. So far as I know, in no city have any very radical steps yet been taken to remedy the trouble. If there have been, that is one of the points I should like to have brought out here; and I should like to make the inquiry of Mr. Knudson. As I understand, the only remedy he suggests is a double trolley system.

MR. KNUDSON. That is the only cure.

MR. BRACKETT. I should like to inquire if there has been any case where a change has been made from a single to a double trolley system, for the purpose of remedying this difficulty?

MR. KNUDSON. The only place I know of where this was the sole reason is in the District of Columbia, where a double overhead trolley has been put in. They were compelled, by Act of Congress, to make the change to a double overhead trolley. There are five Acts of Congress which call for that very thing; two amending franchises, and three granting new ones. Double trolley lines have been completely successful in their operation, both mechanically and financially, in Cincinnati for ten years.

MR. BRACKETT. I was n't questioning whether they had been in operation, but as to whether any single trolley road had been changed to a double trolley, after being installed, for the purpose of remedying this difficulty?

MR. KNUDSON. None that I know of, except the one I have mentioned.

MR. BRACKETT. So far as our own system of works is concerned, I can only say that I have already found evidences of the electrolytic action, and some of them quite serious; and as all of the mains on the Metropolitan Works are of large size, the renewal of them would be a very expensive matter. One particular case, of which I have a few photographs here (Plate III, Figs. 1 and 2), is a main in Cambridge about 400 feet from a power station, where the output is in the vicinity of 6 500 ampères. It is a 48-inch pipe, laid about four years ago, but the main was not connected through until 1897, and was put in use in December, 1898. We have recently made an excavation to examine the condition of the pipe at a point where it passes under the street railway tracks, and where the bell of the 48-inch pipe is only $14\frac{1}{2}$ inches from the bottom of the rail. The pipe was brought near the surface at that point in order to avoid a sewer. The soil was moist gravel. We there found a difference of potential

FIG. 1. — EFFECTS OF ELECTROLYTIC ACTION ON 48-INCH MAIN PIPE, METROPOLITAN WATER WORKS, NEAR CAMBRIDGE POWER STATION.

FIG. 2. — EFFECTS OF ELECTROLYTIC ACTION ON 48-INCH MAIN PIPE, METROPOLITAN WATER WORKS, NEAR CAMBRIDGE POWER STATION.

between the pipe and the rail of between five and seven volts, the pipe being positive; and there were places where, in removing the earth which was encrusted on the outside of the pipe, pieces of the iron pipe from one eighth to a quarter of an inch in depth came off with the earth, and the pipe was then easily cut with a knife to the depth of from one fourth to three eighths of an inch. This has all happened since 1896 or 1897. We have had many evidences of the presence of the electric current on our mains, and have made numerous measurements to determine the strength of the current, but thus far nothing has been done to remedy the trouble, except that the railway company has in a number of instances increased their return wires and lowered the return current potential.

THE PRESIDENT. There is one point I would like to ask Mr. Knudson about, and that is whether he knows of any case where a suit has been brought against the railway company to recover for damages done to the water pipes in which there has been any decision rendered, and if so, whether it has been in favor of the railway company or of the corporation or city bringing the suit?

MR. KNUDSON. There are several cases under way, Mr. President, but so far as I know, there has been no actual decision in any case as yet. There is a case soon to be called, that of Dayton, Ohio, where a suit for damages has been brought against the railway company for something like $80 000. The Peoria case is still on. It will take some time yet to bring these suits to a head and get a decision, but I presume it will not be very long before there will be a decision in some one of the cases which are now pending.

MR. THEODORE H. MCKENZIE.* May I ask just one question? Suppose, for instance, that the rails are properly bonded, that the road is built under approved specifications, with a double bond at every joint on each line of rails, that the hole in the rail is properly brightened to secure good contact and the bond wire of suitable size, and that a proper supplemental bond wire is carried under the railroad crossings, similar to the one you spoke of at Reading, if that would not be ample to carry the current so that there would be no danger of the current leaving the rails and following the water pipes?

MR. KNUDSON. That would carry the larger portion of the current without a doubt, but still there would be some leakage into the water mains. It seems to be impossible to completely confine the current to one path when there are two paths open for it; it is bound to stray

* Civil Engineer, Southington, Conn.

more or less. Then again, these very nicely bonded rails are all right at the start, but they are subject to corrosive action in the ground, where they come in contact with the moist earth, and sometimes to breakage, as at railroad crossings, where cars are passing in two directions, at right angles to each other, and at such places probably there is more danger of the bonds being broken than on the other portions of the road. You cannot keep a conductor of that class always in perfect condition, always a perfect conductor, the same as you might with an overhead wire. Where the track return is broken up by several hundred joints to the mile you cannot depend upon its always remaining a good conductor. Some of the bonds are sure to fail sooner or later.

MR. MCKENZIE. With a supplemental wire carried in the center of the track, would n't that be sufficient?

MR. KNUDSON. Supplementary wires have very often been found to be badly eaten by the action of the current escaping from the wire to the earth. I have seen cases where there was nothing left when the earth was removed but a streak of verdigris, and in other cases it was thinned down to about the size of a knitting needle.

MR. MCKENZIE. Was that because the supplemental wire was not of ample capacity?

MR. KNUDSON. No; because it was subject to the action of the current leaving the wire and going into the earth, and where it leaves it takes away the metal, whether it is copper or iron or lead, or whatever it is. Under such conditions, while they may be all right to start with, it is a very difficult matter to keep them in good condition.

THE PRESIDENT. I would like to call on Mr. Lunt, of Lewiston, Me., who I understand has had some trouble with electrolysis.

MR. CYRUS M. LUNT.* I am not prepared, Mr. President, to make any statement here which I think would be of value, but I have brought some specimens, which I would like to show, of services which I have taken up during the past year. Every one of them has shown a leak under the rails.

THE PRESIDENT. Is there any other member present who wishes to ask Mr. Knudson any question?

MR. JOHN C. WHITNEY.† I would like to ask as to the comparative expense of this double return system and the single trolley systems which are now in use?

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* Superintendent of Water Works, Lewiston, Me.
† Water Commissioner, Newton, Mass.

MR. KNUDSON. That depends almost entirely on the conditions of the railway, whether it has a fairly level road, or whether there are a number of grades to be encountered, and the length of the suburban lines, and all that sort of thing. It might vary all the way from perhaps $600 a mile up to $1 500 a mile, depending on distance and grades. In some places which I have visited, take Pawtucket, for instance, or even Providence, on some of the outlying streets there is nothing at all but the single trolley wire, they depending solely on the trolley wire for the main and upon the rails for the return. There are neither feeders for the trolley wire nor feeders for the track. In a case of that kind, if the positive or trolley wire is of proper size, it would mean principally putting up another wire of the same capacity, and that should not be very expensive. Of course there would have to be two trolley poles on each car; but I think if the railway company would adopt a system of that kind, they would find it very much to their advantage in the saving of power, because there is so much resistance in the rails and in the earth return that the company would in the end be the gainer.

MR. MCKENZIE. Won't you tell us in a general way to what you refer when you speak of the double trolley system? Do you mean another wire overhead?

MR. KNUDSON. Yes, sir.

MR. MCKENZIE. And not another return on the track?

MR. KNUDSON. No, sir.

MR. MCKENZIE. That was tried in Meriden, — one of the first systems which was tried there, — and it was given up as cumbersome in operation.

MR. GEORGE E. WINSLOW.* I should like to ask if you think, with the present system of a single overhead wire, with rails bonded as you speak of and return wire, the rails could be made large enough or heavy enough, or the return wire could be made large enough or heavy enough so that the two in combination could take all of the current that is put out without its being carried back, in part, by the water mains?

MR. KNUDSON. It might take a large portion of it, but not all. There would always be some escape. We have made tests in cities where they have heavy girder rails, ninety pounds to the yard, well connected and well bonded, but there was no place where we did not find some difference of potential between the rails and mains.

* Waltham, Mass.

Sometimes it would run up to a volt, generally it stood under one volt. When the rails are in such good connection and the road is so well built as that, the readings generally are under one volt; but that is sufficient to cause damage to the water mains, if it is given time enough.

MR. CHARLES K. WALKER.* Mr. President, I should like to know what we are going to do about it?

I thought when I got through with cement pipe I was n't going to have any more trouble, but things grow worse and worse, and it seems that this iron pipe is worse than the cement pipe ever was. I never saw any worse-looking specimens of cement pipe than I have seen here to-day of iron pipe, and I would like to know what we are going to do about it. Is there any way in which we can fix it, or have we got to stand it? Suppose you go to an electric railway company and tell them they are damaging your pipe, and you would like some recompense for it, what would they say? Why, the chances are they would say they have just as much right under their charter as you have under yours, and you must take care of your own pipe. And I do not see any way out of it for us superintendents except to grin and bear it, and when a pipe gives out put in another pipe, the same as we did with the cement pipe. But that is not a very good thing to contemplate; I do not like to have that in prospect. I came down here to get some information as to how I could find relief, for things seem to be growing worse, and the pipes are growing worse; but if nobody can tell me what to do, I shall have to go home and tell my folks there is no hope for us, that we are goners. I have found, lately, trouble in the service pipes like what the gentleman from Lewiston has shown us; it has begun there, and where is it going to end?

Well, I do not know as it makes much difference to me. I am an old fellow, and you young fellows have got to stand it, I guess.

MR. JOHN C. CHASE.† I would like to ask Mr. Knudson if it is practicable to tell whether a pipe system is in any danger before there is any direct manifestation of the effects of the current, or, in other words, if the electrical expert can step in and tell us that it is time for us to be getting after the electric railway company to bond their rails or provide a proper return for their current, because our pipes will begin to show signs of disintegration ere long. This is an in-

* Superintendent of Water Works, Manchester, N. H.
† Civil Engineer, Derry, N. H.

teresting question in the case of a small water-works system with an electric railway in close proximity to a portion of its mains. Most of you, I presume, are familiar with such cases.

There has been no reason to apprehend any difficulty, but yet, according to what the gentleman has told us this afternoon, unless there is a proper return provided for the current, disintegration is going to take place, or is taking place already, and it is only a question of time — we do not know how long — before the whole system will be destroyed. Now, what I would like to know, to repeat, is whether the scientist can tell us the certain relation between the amount of work which is being done by the electric railway system and the pipe system that must not be exceeded, or can say positively when it will become necessary for the company to provide some method of return for the current, in order to save the pipes, before the story is told by the pipes themselves.

MR. KNUDSON. That is a little difficult question to answer, as there is so much in it. In order to ascertain, first, what damage is going on, an electrical survey is generally made, and from that survey we can understand something about what and where the damage is. For instance, if we find in the positive district that the readings are fairly high, it is a pretty sure sign that the pipes are seriously damaged already. In such cases we have excavations made, uncover the pipes, make a personal examination, and in that way find the acute points of rapid electrolytic damage.

Now, in regard to making the railway companies pay. In some cases it works all right, and in others it does not. The railway companies generally do not seem to be inclined to admit that the pipes are damaged by their railway currents if there is any possible way out of it. In one case I had a talk with the president of a railway company, who is an electrician; he was standing on the edge of an excavation, and I was down in the hole scraping the graphite out of two or three soft places; I held up some in my hand and showed it to him, and said: "That is what you are doing to these pipes; you can understand that, as you are an electrician." Well, he could n't very well get away from that kind of evidence; that was too plain. Still, they do not like to admit that pipes are being destroyed by electrolysis. They sometimes admit that pipes have been damaged by their currents, and pay the bills, but it is not always done.

MR. MCKENZIE. May I ask just one more question? Is it to be

expected that this damage by electrolysis will occur throughout the entire system? Is n't it confined practically entirely to a point near the power house, where the current leaves the pipes for the power house, or at such railroad crossings as you have described, or is it general throughout the entire system, or anywhere except where the track runs over the pipes?

MR. KNUDSON. It is both. Generally we find the acute positive condition near the power station; that is, where the current coming back on the pipe lines goes back to the rails. That is where the pipes are positive and where electrolytic action is most pronounced. But, as I said in the paper, very often we find these positive districts in negative sections of a city. There was one place I mentioned where there were four different localities widely apart and some distance away from the power station. I found that in one case there were new rails laid on a street, and at the terminus they had left about two squares of old rails in. Without a doubt those old rails were not bonded. We found there a difference of potential of 42 volts, the highest readings I have found anywhere. Just where the new rails left off and the old ones commenced there was a high positive reading, the current going back to the new rails. That is an instance of positive readings in a negative district. Then there are cases where the bonds have been broken on railway crossings, and anywhere where there is an opening in the rail return, it is very apt to cause a positive reading in that location, where the current after leaving the rails at such breaks will go back to the rails again somewhere in that vicinity on the other side of the break.

MR. MCKENZIE. Will the current return to the rails or to the supplemental wire immediately beyond the break, or will it follow the entire distance to the power station?

MR. KNUDSON. Some of it does return to the rails. It will go both ways. A good deal of it will come out at the nearest point where it can get a good connection to the rail return; but a portion of it will go on the main, following it down to the power station.

A MEMBER. Is it fair to suppose that all pipes in streets where there are railway tracks are being affected as distinct from pipes laid entirely outside of streets where there are no railway tracks?

MR. KNUDSON. Yes, sir; it is quite fair to suppose that, more or less, according to how well the rails are bonded, and how well the track returns are equipped with feeders. Of course, if they have proper overhead wires connected with the rails, that helps the rails

out. But in most cases on suburban lines they don't have any track feeders, but they depend on the rails entirely; and those are the places where we get the highest potential in the negative districts.

Mr. Frederic P. Stearns.* As I understand it, Mr. President, Mr. Knudson has told us very distinctly that a complete remedy for this trouble is a double trolley, with two overhead wires, or with insulated underground wires. Many of us may think it is impossible to obtain this complete remedy soon. It is a good thing to aim at, perhaps we will get it before long; but there is a difficulty which demands attention at the present time. Can Mr. Knudson tell us how much we would gain if we could have twice the capacity in the wires and rails that convey the electricity back to the power station; or, in other words, is there any definite relation between the damage that is done by six volts and the damage that is done by two volts, or between six ampères and two ampères, — whether by reducing the pressure or the quantity we can get a degree of safety from the action of electrolysis that will add many years to the life of the pipes?

Mr. Knudson. I see what you mean, I think, sir, — simply adding more copper to the return. Of course, as I think I have said in the paper, that modifies the escape very largely. The acute places in a city, where there are high differences of potential, will be comparatively few in a case of that kind, and if such a system could be kept continually in perfect shape, it would be a great relief to the water mains. There would then be slower action, resulting in a longer life to the pipe, which might be extended over years instead of months; but I think it is practically impossible to keep up a perfect track return.

Mr. G. H. Snell.† I would like to inquire of Mr. Knudson whether a pipe which has a track running directly over it is much more liable to damage than it would be if the track was on the opposite side of the street?

Mr. Knudson. Yes, sir, it is. I recall just now a similar case to that. We found in Providence, R. I., on Smith Street, a railway line running over a 24-inch main, from one reservoir to another, for a distance of about two miles, and on that main I found quite a heavy flow of current. The street was quite broad, and there was no reason, that I could see, why the rails could not just as well have been put on the opposite side of the street, and in that way give

*Chief Engineer, Metropolitan Water Works, Boston, Mass.
†Superintendent of Water Works, Attleboro, Mass.

some relief; that is, there would not be so much flow of current to the water main, on account of its not being so close to it. It is not a good plan, if it can be avoided, to allow rails to be placed over a water main.

MR. SNELL. I asked that question because in the town of Attleboro, where I come from, this last summer the selectmen granted a franchise for a street railway track directly over our force main from the pumping station, running about one mile. The pipe is about in the center of the track, and it seemed as though the track should have been put on the other side of the street, and the water department used every influence possible to have it so located; and yet the selectmen permitted it to be laid over the pipe, thereby not only making it more liable to be damaged, but making it very much more difficult and expensive to make repairs.

MR. T. C. GLEASON.* I would like to ask a question. In a town twelve miles below my town is an electric railway power plant, and the cars run into my town over about a mile of track. Now, would that be likely to affect our whole system?

MR. KNUDSON. That is a little difficult to answer without having further data and looking the matter up. Undoubtedly your system would be in what is called a negative district, if the power station is twelve miles away, but some of your pipes may be used as auxiliary return for the track circuit, and some of the current will no doubt go by that route.

MR. GLEASON. What I wanted to know was whether it would affect only the pipes near which the rails go, or whether it would affect them all over our system?

MR. KNUDSON. It might affect them anywhere on the system.

MR. GLEASON. Just the same as if the road really ran over the whole system?

MR. KNUDSON. Yes, sir; depending, however, on local conditions.

MR. ROBERT J. THOMAS.† I have been told that the city of Lowell, which I represent, has been especially fortunate in not having any trouble to speak of from electrolysis. The first road was equipped with electricity in 1889, and we have found up to this time comparatively little trouble on account of electrolysis. In talking with the general manager of the road on several occasions, he has told me that the reason of it is the perfect or almost perfect bonding of the

* Superintendent of Water Works, Ware, Mass.
† Superintendent of Water Works, Lowell, Mass.

rails, and also the connecting of a return wire with the rails in various places along the line. Up to within two years ago we did n't have a single instance of trouble that I know of. Since then we have had a few cases where service pipes have corroded, which I could only account for as due to electrolysis. In every instance of that kind we have found that the pipe was eaten away under a conduit which was laid by the New England Telephone Company.

MR. KNUDSON. Was the telephone conduit an iron conduit?

MR. THOMAS. No. It is made of some kind of earthen pipe, I think, and it is covered with a coating of cement. We had the soil tested there, and the greatest potential that was found was about one volt; and it occurred to me whether the fact that there was such a small pressure, such a small voltage there, would not account for the service pipes being attacked instead of the main, — in every instance where we have had any trouble with service pipe we have also uncovered the main pipe and have found that practically as good as when it was laid, not the slightest effect from electrolysis noticeable on it, — and whether the return wires and rails allowing such a little current to go to waste as is represented by about one volt, would not exempt the main pipe from being attacked; and whether in such a case as that we would only have to look at the service pipe for damage; in other words, whether the amount of voltage has anything to do with the size of the pipe attacked.

MR. KNUDSON. If the track returns are in such good order, it would spread the trouble over a longer period of time. Undoubtedly it would show on the service pipes first, because as a rule the service pipes are nearer the rails and frequently made of lead. The telephone conduit, not being of metal, I do not think cuts any figure in the case. But if the soil is favorable, a low voltage, even as low as .001 of a volt, is liable to cause electrolytic action and damage the pipes. Sometimes, if the soil is sandy and fairly dry, we don't find it; the current is coming out somewhere else. It must come out somewhere; whenever it goes in, it must come out again on some portion of the system. It is difficult to tell how much damage is being done on the main pipes because we don't know how much current is flowing through them. There may be considerable current flowing through, and it would n't show itself except at the joints. If a little current was flowing through, you would find it, perhaps, in the course of time in the shape of pittings on the positive side of the joints, that is, on the side that is farthest away from the power station, whether

the spigot side or the bell side. We have found it so in a number of cases. Of course we can seldom see the inside because the pipe is in service, but on the outside we very often find pittings. If it is on the bell end it is often at the edge of the bell, as was shown by the picture on the screen, and if it is on the spigot side it is quite near the bell joint. With that low potential your trouble would be extended further into the future, that is, if they keep up these conditions. We don't know what acute points there are, perhaps, in the outlying districts, or at a distance from the power station; there may be damage going on there which no one knows anything about. It was quite a revelation when on my examination in Reading I found these different places. It was a surprise to the railway people as well as to the water-works people to see what damage was going on at places which they had no idea of; for example, at the railroad crossing. That is a point which is extremely important, I think, because it showed not only danger to human life, but a ruined water main was actually found there.

MR. THOMAS. I will say that in these cases to which I have referred, I reported to the railway people, and they immediately put a test car right over the line to find out if there was any leakage; and they were very anxious to prevent it in case there was, because, as they said, they did n't want to lose any power by having their current go to waste, so they were just as anxious to have any leakage from their system stopped, apparently, as we were.

MR. KNUDSON. I find it is often the case that fair-minded railway people are just as anxious to have any leak in their system discovered and stopped as the water-works people are. In some cases during a survey, I have been requested by railway officials, in case any bad spots or leaks were developed, to report them, together with suggestions for improving same, and they would correct them as soon as possible. The trouble is, however, that while such special leaks may be improved upon by rebonding the rail joints, it is not, generally speaking, an effective remedy for electrolysis, for the reason that, improving special leaks, while most important at the time, is no guarantee for the future so long as the rails are used as a return, and that is the point we are trying to make. It is not only the present, but the future safety of water mains which should be considered in looking for an effective remedy from electrolysis.

MR. FREEMAN C. COFFIN.* If I understand the speaker, there

* Civil Engineer, Boston, Mass.

will be a saving to the companies by the construction of a double return wire in the saving of power. I should like to ask him if he states that as a general principle, or if a mathematician can show that in figures; if it is able to be shown in figures to the companies in a way that will be convincing, as an offset against the fixed charges or cost of operation.

MR. KNUDSON. I do not know of any recent change from a single trolley to a double trolley, except in the District of Columbia; but I have seen estimates that have been made by competent railway contractors. Some of them claim that a saving can be made in power of something like twenty to twenty-five per cent. by having a proper insulated metallic return, instead of depending on the rails as a return, and having the current stray off into the water pipes, and being obliged to overcome the resistance of the rails and the earth. There is no doubt that it would be an advantage to the railway companies if they would more generally adopt the insulated return.

MR. FRED. BROOKS.* I have been told that while it might be expensive for an existing railway to change its system, it would not be particularly expensive in laying out new work to arrange the system so as to avoid these destructive consequences; that one safe method would be to use the three-wire system. Whether that means what has been termed here a return wire or something else, I should like to learn. Another statement which I did not understand was that the electrolytic effect could be greatly reduced by working a line in sections by some system in which there is a crossing over of the current in different parts of the line with changing over the trolleys; I should be glad to have that explained.

MR. KNUDSON. The three-wire system has not been put into use anywhere, so far as I know. There are serious objections to it because it necessitates a balancing of both sides. You must have as much load on one side as on the other, and that is practically impossible in railway traffic. In speaking of a return wire I refer to a double overhead trolley or a double underground trolley, both conductors insulated from the earth, and from each other of course, making a complete insulated metallic return.

MR. GEORGE A. STACY.† I had a little experience, fortunately on a Sunday evening, which I will relate. We had a leak in a service pipe, and on taking it out I decided from what I saw that it showed

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†Superintendent of Water Works, Marlboro, Mass.

the effect of electrolytic action. This pipe lay at right angles to the street railway line. The original rails of our street railway were very light, designed for a horse-car track, and they changed to electricity as a motive power, being one of the first electric roads installed in the State. Some of the old rails were replaced with heavy girder rails, but the light rails remained on this particular section for a long while. At one point, beyond where this service pipe to which I am referring crossed the track and the power station, there was a switch which was in pretty bad condition. I know that two winters ago they did n't have to put any salt on it to keep it thawed out; it was boiling some of the time, and they let it go, for at that time the company was n't very wealthy. Well, I thought I was safe, for at the power station at that time, very near the dynamos, was a four-inch fire supply pipe for their sprinklers, and I came to the conclusion that if there was any trouble it would follow along and show itself at the terminal on that pipe; and the people in the power house would get it first, and know how good it was; and I felt as if I did n't care how long it would take me to get down there and shut the water off.

But this thing occurring nearly half a mile away from the power station, and it having all the ear-marks of electrolytic action that I have read or heard of, it struck me that while I thought I knew something about it before, I really did n't know anything, by its showing evidences of its effect on this pipe, when it had a good lead clear down to the station. This was a cement-lined service pipe, and the lead connection shows evidence of pitting all over it, and it has scales on it which look very much like those on a piece of iron that has been heated very hot and taken out and cooled, although the scales are granular; that is, you take it and scratch it with a knife or with your thumb nail and it crumbles all up. And what I would like to know is whether or not these facts, under such conditions as I have described, would warrant a man in thinking that this trouble was caused by the electric current at that point. The main pipe is located close to the track on the outside, say within two feet of the rail; the service pipe crosses under the track into a building; and if this has happened in one case, are not all the service pipes on that side the whole length of the street likely to be in the same condition? And if they are, is it worth while to go to bed at all this winter? As I understand the subject presented here by this very able and interesting paper, it is only a matter of time when this electrolytic action is going to destroy

the pipes unless there is a change in the system to keep the current out of the ground; and if this is not done, the only thing we can do is to try to get the railway companies to fix their rails up, so as to make the current in the ground as light as possible, so the pipes will last at least as long as we live, or until we go out of the business, and then some other fellow can have the trouble.

THE PRESIDENT. I would like to ask Mr. Knudson if I understood from him that he had some form of ordinance he suggested to the city of Providence and to the city of Pawtucket in regard to the granting of franchises to electric railway companies, and that he advised them to adopt? If he has such a thing, I have no doubt it would be of interest to some members of the Association.

MR. KNUDSON. It was not in regard to the cities of Providence and Pawtucket, but I made the remark, I think, that I had a copy of an Act of Congress which covered the construction of electric railway lines in the District of Columbia; and if you would like to hear it — it is very short — I will read it. Under section three it is provided that "the motive power shall be electricity, and if the trolley system is used a return wire of equal capacity to the feed wire and similarly insulated must be provided, and each car shall be equipped with a double trolley. No portion of the electrical circuit shall under any circumstances be allowed to pass through the earth, and neither pole of any dynamo furnishing power to the line shall be grounded." That is very short, and I think it is to the point.

THE PRESIDENT. I would like to call on Mr. Connet.

MR. F. N. CONNET.* I wish to remark that in these days when there is so much literature with reference to 8 000 volts and 10 000 volts, it seems almost as if two volts was too small to consider. But I believe that at Niagara Falls, where they are depositing by electricity several tons of copper and aluminum every day, the voltage is but two volts. That is the first thing I wished to say.

The second point is this: I think there is considerable danger that, with non-experts, plain corrosion will be mistaken for electrolytic action. I recall some photographs that I saw some years ago of rails that were taken up from a tunnel on the Lehigh Valley Road in the western part of New Jersey. These rails when laid were about sixty pounds to the yard, and they had been corroded in a very few years till the weight was only about thirty pounds per yard. Now if that had happened to-day everybody would have said it was due to

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electrolytic action, but I think there was no electricity within twenty-five miles of that tunnel. In that case it was due to the absorption by the moisture of the sulphur from the locomotive gases and the formation of a sort of weak acid solution. The photograph of those rails looked exactly like the photographs that Mr. Knudson has shown us this afternoon. I suppose that an expert can determine the difference between corrosion and electrolytic action, but I think there is great danger that some of the rest of us might mistake the one for the other.

Then there is a third point, and that is, the method suggested for getting around the difficulty. Now, I have a method which I think will get around the difficulty, and I think, perhaps, it will be adopted before the double trolley system is adopted. That method is for the railway company to swallow up the water company, and then we will not hear much more about the trouble from electrolytic action.

MR. KNUDSON. The deposit of copper or other metals in large amounts at only two volts pressure merely means a low resistance between the electrodes, such as always exists in an electrolytic bath of this kind. Now, we find that very thing, only on a different scale, in railway electrolytic investigations. For instance, in soil where it is very wet, or perhaps where there are alkalis or acids that lower the resistance, a larger amount of current would flow, and the pipe consequently be very soon ruined; while in other cases, even at higher voltages, which may run up to twenty or thirty volts, if the pipe is in a sandy soil or a fairly dry soil, the action may not be at that point, but at some other place where the earth is a better conductor. Sometimes if the soil is impregnated with salty material, or a small percentage of ammonia is present, the action is more rapid. Unusual deposits in the soil, such as are discharged from factories or are present in garbage heaps, or such as might be caused by locomotive gases in the tunnel mentioned by Mr. Connet, sometimes produce chemical action and results similar to that of the electric current; these conditions are rare. Such action and results never occur in ordinary soil unless caused by electric current, and ordinary corrosion need never be mistaken for them.

MR. CONNET. The only point I meant to bring out was that under certain conditions we ought to be thoroughly frightened at two volts, even though it looks like a very small amount, because that is in itself sufficient to do a great deal of damage.

MR. KNUDSON. It certainly is, particularly if the soil conditions

are favorable, and they usually are favorable in many places in a city.

MR. BRACKETT. If there is no further discussion of Mr. Knudson's paper, I wish to say that I think the discussion this afternoon has certainly shown that this is a subject in which the Association is very much interested; and I wish to move now that a vote of thanks be given to Mr. Knudson for his very interesting and instructive paper.

The motion was adopted by a rising vote.

LANDSCAPE PROBLEMS IN THE IMPROVEMENT OF SPOT POND RESERVOIR, METROPOLITAN WATER WORKS.

BY FREDERICK LAW OLMSTED, JR., LANDSCAPE ARCHITECT, BROOKLINE, MASS.

[*Read September 20, 1900.*]

Mr. President and Gentlemen of the New England Water Works Association, — It is a privilege that I value and an honor which I think somewhat unusual that a member of another profession should be called upon to address a body of technical men on their own subject. It is rather a dangerous privilege, too, for I may be put in the attitude of assuming to instruct able water-works engineers and experienced superintendents how to do their own business.

If anything I say to-night should seem to indicate such an attitude, I assure you in advance that it is quite unintentional. I no more think of assuming to be a water-works engineer or a professional reservoir builder than I think of pretending to be a painter of landscapes, though both professions touch at points upon my own.

Almost every constructive work is planned, not absolutely and completely by the mind of one man, but by coöperation, usually by the coöperation of many minds. There may be, indeed there generally is, one controlling designer, but his assistants do not merely carry out his orders like so many automata. The man has never been born who could know all there is to be known bearing on any subject, or who could think of all the ideas applicable to any one subject. For this reason those with and through whom any designer works help him to plan better as well as quicker. Barring exceptional strokes of genius, all the best constructive work is planned in this coöperative way; and wherever constructive work becomes complicated in character, or involves the consideration of more than one point of view, it is almost essential that there be conference between men of different training. Even if one point of view be clearly supreme, a master of that aspect of the case will be helped by the ideas of those who can see the problem from another side.

In the matter of reservoirs, I speak, then, as one who would help by contributing knowledge of a special subject incidental to the main purpose for which they are ordinarily built.

In the case of Spot Pond Reservoir, which was created in the midst of lands set apart for park purposes, the question of appearance had, it is true, unusual weight, and it is partly because the problem of constructing a reservoir in a park has come up elsewhere and is likely to come up again that I am especially glad, as a park-maker, to address you as reservoir makers; but there is another aspect of the case that I cannot refrain from touching upon here. It does not often happen that the site chosen for a park proves to be needed for a reservoir, but every reservoir from the mere fact that it is an open sheet of water has a strong element of beauty, and it has always seemed to me that it would be possible for many a municipality to get much more return for its money spent upon reservoirs if that fact were recognized, and if a well-directed effort were made to render the potential beauty of these sheets of water positive and available.

A fire-engine house is a purely utilitarian structure, but it is well recognized that, so far from being ugly, it may be made one of the interesting and attractive buildings of a city without the expenditure of much more money than is required to meet the absolute material requirements. It is not a question merely of ornament or primarily of ornament, as too many engineers seem to think. The modification of proportions and slight changes in the form of necessary details are enough to change an ugly or commonplace building or bridge to one that is distinctly pleasing.

And so it is with reservoirs. I believe that none of the work done by the engineers who controlled the improvement of Spot Pond was unreasonable or fantastic from a strictly engineering point of view, in spite of the fact that they adopted many of the suggestions of a landscape architect; yet Spot Pond when completed will have a very different aspect from that of the typical distributing reservoir, and one more pleasantly harmonious with the surrounding landscape.

When the work of the Metropolitan Water Board began, there were in the rough upland of the Middlesex Fells several natural and artificial ponds utilized with their limited watersheds as sources of supply by the neighboring towns. The largest of these, Spot Pond, had been in view from the beginning of the Metropolitan project as

a suitable location for a northern distributing reservoir for the district, to supplement the very inadequate reserve at Chestnut Hill, which amounted in 1898 to only about two and one half days' supply for the whole district.

Spot Pond lies in an elevated rocky valley of irregular form which seems originally to have had its outlet to the southward, but which was so completely blocked by a dam of glacial deposits that the pond thus created found its overflow at a low point in one of the enclosing ridges, and has ever since run off to the eastward. (Fig. 1.) On account of its origin, the pond was naturally shallow toward the northern or up-valley end, and the original shallowness of this end has been greatly increased by the material carried in by the streams and by the accumulation of swamp vegetation working out from the margin. The rough tract of upland, known as the Middlesex Fells, in which the pond is situated, is about two miles square, and contains several other more or less interesting valleys, and countless crags, hills, and basins almost uncultivated and unoccupied, although quite surrounded by populous towns. Some of the other valleys had been artificially dammed for water-supply purposes, and the immediate shores of these reservoirs, as well as of Spot Pond, had thus come under water-board control.

On account of the exceedingly interesting scenery of the Fells and the fact that they were as yet wild and unoccupied while close to a large population, nearly all of the private lands of the region (amounting to eighteen hundred acres) were purchased in 1894 by the Metropolitan Park Commission, for the benefit of much the same district as that served by the Metropolitan Water Works, and the care and control of the lands held by the local water boards on the margins of the reservoirs were then turned over to the Park Commission. The chief conditions, then, which confronted the Metropolitan Water Board in 1899, when the method of utilizing Spot Pond as a distributing reservoir came up for definite decision, were these: —

Parts of the pond were shallow and mucky, with the result that a perceptibly disagreeable taste and odor were given to the water stored in it, thus making some radical treatment of these shallow and mucky portions imperative. (Plate I, Fig. 1.) The pond when up to its highest normal level (154 feet above Boston base) contained a supply of 758 000 000 gallons in its upper twelve feet, the portion below Elevation 142 being unavailable. This amount, added to that of the Chestnut Hill Reservoir, would raise the available

FIG. 1. — SPOT POND IN 1895, BEFORE ITS IMPROVEMENT.
Scale, 1700 feet to an inch. Contour interval, 5 feet.

supply within the district to only 11.7 times the daily consumption, and it was the opinion of the board's engineer, Mr. Stearns, in view of the steadily increasing daily consumption, that a much larger storage ought to be provided. Incidentally an increase in the height of the water was to be desired for the sake of the increased pressure in the distributing system. Furthermore, the fact that the pond was surrounded by a reservation of the Metropolitan Park System, and indeed was itself a most important landscape feature of that public domain, made the question of appearances of far more obvious importance than is usual in the case of reservoirs. Clearly, if the community had seen fit to spend nearly a million dollars for the sake of acquiring and preserving certain scenery, any radical changes in an important element of that scenery should not be made without a careful consideration of the landscape effect and a clear conviction that any damage to this valuable scenic asset was more than counterbalanced by other gains. (Plate I, Fig. 2.)

It was probably owing to this last consideration that my firm was called in to consult with the engineers, in order that we might help them by suggestion and advice as to the landscape effect of various methods of accomplishing their purposes. The quality of results from the strictly engineering point of view was the prime consideration, and no one could judge better of this than the gentlemen in question. The appearance of the results, however, though secondary, was of such importance as to determine the election of methods when engineering considerations did not preclude a choice.

It was while the plans were still in a formative condition that our suggestions were made. The preliminary plans were furnished to us by the engineers, and we then prepared detailed plans for the grading and such other details as we thought likely to affect the landscape. (Fig. 2.) If any particular of our plans tended, in the opinion of the engineers, to interfere with the excellence of the reservoir as a storage place, that particular was at once modified; but when some feature of the plan, as not infrequently happened, without affecting the engineering excellence of the reservoir, involved more expense than some other equally efficient arrangement, there was a discussion of merits. An estimate of the additional cost was made by the engineers, and if we then really thought the probable gain in appearance worth the difference in cost, we stated our opinion, backed by our reasons. We were cautious and conservative in urging such extra expenditures, and the engineers were most fair-minded

FIG. 1. — SHALLOW FLOWAGE AT NORTHERN END OF POND, BEFORE IMPROVEMENT.

FIG. 2. — PICKEREL ROCK, BEFORE IMPROVEMENT OF POND; SHOWING FOLIAGE TO BE DESTROYED BY RAISING WATER LEVEL.

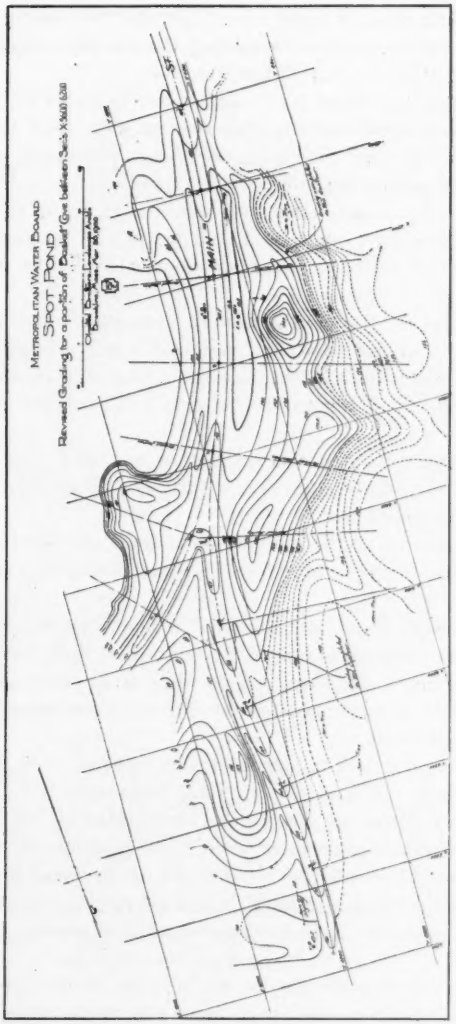

FIG. 2. — GRADING PLAN.
Scale, about 192 feet to an inch.

in their consideration of such cases, with the result that there were very few points strongly urged by us that they felt unable to accept.

Five alternative plans for improving the reservoir were seriously considered. (See Fig. 3.) They were: —

A. Leaving the water level unchanged, to excavate the muck and the loam-covered sand from the shallow portions of the pond so as to give a minimum depth of ten feet. Estimated to provide 1 006 000 000 gallons capacity.

B. Leaving the water level unchanged, to excavate as in Plan *A* except in the mucky western arm, and to fill that so as to exclude the water from it entirely. Estimated to provide 899 000 000 gallons capacity.

C. To dike off the mucky western arm, dike other low points on the margin of the pond, and raise the water six feet after excavating enough material from the bottom to give a minimum depth of fourteen feet. Estimated to provide 1 354 000 000 gallons capacity.

D. To raise the water level six feet as in Plan *C*, but to extend the excavation to the western arm. Estimated to provide 1 448 000-000 gallons capacity.

E. To excavate all the shallow portions of the pond as in Plan *D*, but to raise the water nine feet. Estimated to give 1 764 000 000 gallons capacity.

The landscape architects submitted a report on the comparative value of these schemes as judged by their effect upon the landscape, showing the immediate harm or gain from each, and what opportunity there was in each case for the future concealment or natural healing of the injury.

Roughly summarized, the report was as follows: —

. *Plan A* would not injure the existing landscape, but on the contrary would improve its appearance by maintaining the pond constantly at its normal high-water level. The great amount of material excavated could be made into a hill at the northern end of the pond, and when clothed with vegetation would strengthen the frame of the pond where its shores were dangerously near to uncontrolled private property.

Plan B would preserve the beauty of most of the shore growth, but would render the west shore tame and uninteresting, and cut short the east and west views of the pond. If the road were shifted so as to pass to the east of Deer Hill and along the new shore

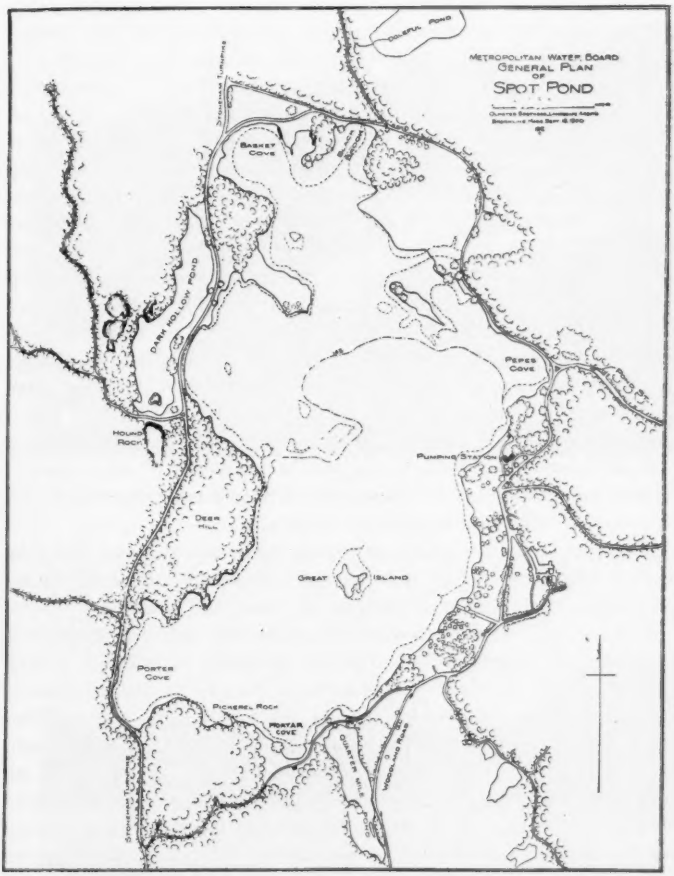

FIG. 3. — GENERAL PLAN OF SPOT POND, SHOWING OLD OUTLINE, AND OUTLINE AS FIXED BY PLAN E.

line, the loss of landscape effect would in time not be noticed, but would still be real and permanent.

Plan C had all the objectionable features of Plan *B*, increased by the need of a dike considerably above the level of the land behind it, and had also all the disadvantages of a change in water level.

Plans D and *E* differed only in the amount of the proposed raising, and a careful study showed that while the landscape would be seriously injured by raising the water even two or three feet, the amount of the damage would be little greater with nine feet than with six. The reason for this was that the best of the foliage framing the pond and overhanging its borders was borne upon the water-side trees, which had developed in the full sunlight offered by the open pond, whereas most of the trees further from the water, growing behind this vigorous margin, had lost their lower foliage and become tall and "stemmy." This condition was modified at various points about the pond, but on the whole, Plan *D* offered no considerable landscape advantages over Plan *E*, and was far less desirable from an engineering point of view.

Plan *E* was finally adopted. (See Fig. 3.) This gave the greatest storage capacity, and though temporarily destructive of much beauty, offered the possibility of making the finished work harmonious with its surroundings and not glaringly artificial.

The chief landscape problems coming up in carrying out this plan were briefly these: Tree cutting, shore treatment, form of dikes, disposition of surplus fill, relocation of roads, and planting.

The first tree cutting consisted of a wholesale removal of all trees standing lower than Elevation 163, the proposed water line. Then a second cutting was made, removing such trees as by their weakness or lack of lower branches injured the new forest edge. Meanwhile, a one-foot contour map was made at a scale of forty feet to the inch, showing the conformation of the ground both above and below the proposed water level. On this map individual trees were located at frequent intervals. Each tree so located was marked by a numbered tag and was designated by a corresponding number on the map, an arrangement of great value in studying upon the ground the exact and detailed relation of any proposed grading to the existing conditions of surface and vegetation without the expense of actual staking out. A somewhat minute regard for this relation is essential to agreeable landscape work, and in many cases it is impossible to perfect it without repeatedly "trying the plan on the ground," either by staking

FIG. 1. — PEPE'S COVE DIKE, LOOKING NORTH ALONG CREST.

FIG. 2. — GRAVEL SHORE, PORTER COVE.

out the finished grades or by using a sufficient number of accurate reference points, such as cross-section stakes or the more conspicuous numbered trees.

The shore treatment was an attempt to give to the new shores an appearance not conspicuously different from that the pond itself would have given them in ages of erosion. Rocky ledges were simply stripped of soil and allowed to rise from the water in whatever shape they happened to be. This is, perhaps, the most satisfactory kind of shore. It is perfectly clean, perfectly stable, and most natural in appearance. Where there was no outcrop, the shore was formed of bowlders, gravel and bowlders, gravel, or sand, as the surroundings suggested. Where a fairly steep slope came down to the water, as was the case along a large part of the shore, it would be natural for the water to wash away the finer material of the banks, leaving exposed, in course of time, a bowlder shore. Such shores were made around much of the pond. They differ from ordinary riprap in the intentional unevenness of their surface, and in the use, as far as practicable, of weathered surface stones. (See Plate II, Fig. 1.) Gravel with bowlders, or gravel alone, was used where the slopes were more gentle. (Plate II, Fig 2.) The bowlders were, as far as possible, sunk for about half their diameter into the gravel, as nothing can be more awkward and artificial in appearance than a sprinkling of bowlders set about on top of a finished surface.

Sand beaches forming broad shelves at the water level with a slope of about one in twenty were made on some concave stretches of shore. (Plate III, Figs. 1 and 2.) A sand beach, and in less degree a gravel beach, will not remain upon a point unless all the neighboring material is sand as well. It is carried away by the waves, and the underlying rocks, if there are any, are exposed. But on a nearly flat or concave shore no form of protection is more resistant or secure than a beach of sand when once its breadth and slope are adjusted to the wave conditions, while the constant agitation of the sand interferes with objectionable plant growth in the narrow band of shallow water.

Whatever shore treatment was used, all soil was stripped to the contour two feet above the proposed water level, and the shore treatment carried up to this line in order to prevent wave action from carrying into the pond any pollution from the banks.

The two ponds which were diked off from the main reservoir, Dark Hollow Pond and Quarter-Mile Pond, received no shore treat-

ment. The water in these ponds is not to be used, and they are so small that wave erosion will probably never strip the root protection from their banks.

The other elements of the landscape problem are so interdependent that perhaps the simplest way to deal with them is to take up in order the important localities around the pond, showing briefly what was done in each case, and what effect was aimed at.

At Pepe's Cove, as the map shows, Pond Street comes up hill to the water. This rise was exaggerated by the necessity of building a dike across the opening in the pond shore, and, unless remedied, would very forcibly and unpleasantly suggest the artificiality of the embankment. A spur of filling was run out from the hill to the north, and the road, on passing this, was divided by a triangle. (See Plate II, Fig. 1.) Both sides of Pond Street and the triangle are to be planted, and when the trees are grown it will be impossible to see the pond and the descending hill on Pond Street at the same time from the road. The spur of filling also strengthens the dike as seen from across the pond, disguises its artificiality, and ties it in with the adjacent hill.

To the north of Pepe's Cove, the shore along which Pond Street runs presented a stiff, artificial line of causeway. This was improved, on raising the pond, by shifting the road inshore, and filling in a slightly irregular way, both as to shore line and profile, between the road and the pond. This strip is to be planted at points where the ground rises and projects into the pond, but left open at other points where planting would interfere with the best view of Pepe's Cove.

The large low-lying field on the northeast side of the pond was occupied by a long dike to hold the water back from the swamp east of Pond Street. This dike was made very broad, sloping very gently from its greatest height near the pond and covering most of the meadow to a considerable depth with sand and other material excavated from the pond.

The next dike, at the valley of Black Brook, which connected Doleful Pond with Spot Pond, was formed like a series of small hills, thus disposing of surplus fill and minimizing the artificiality of its appearance. These elevations were so arranged that on going along the road toward the west, one would see first the pond and not the depressed meadows, and then the meadows and not the pond. (Plate IV, Fig. 1.) Farther on in the same direction the road forks, the right-hand branch being the old road, the left-hand running

FIG. 1. — SAND BEACH ON LEFT; REGRADING OF SHORE AT PEPE'S COVE.

FIG. 2. — LEDGE AT PEPE'S COVE; SAND BEACH TO RIGHT IN FOREGROUND.

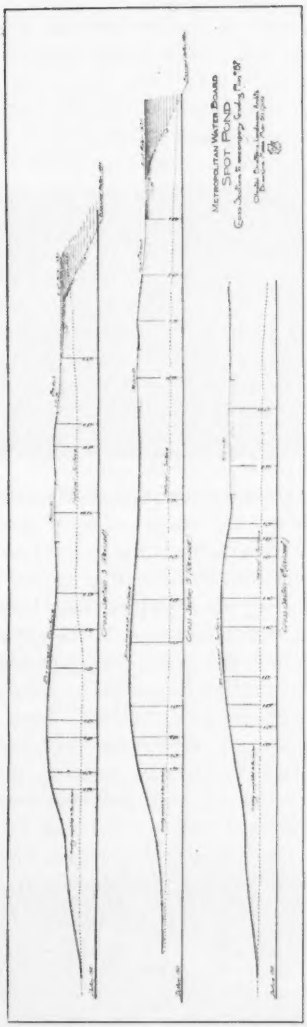

FIG. 4. — CROSS SECTIONS OF GRADING IN FIG. 2.
Scale, 60 feet to an inch.

over the fill north of Basket Cove. This long, broad, curving hill disposed of a great amount of surplus material, which was carefully modeled to harmonize with the existing topography. (Plate IV, Fig. 2.)

In the course of the work, changes from the estimated quantities of excavated material necessitated adjustments in the grading plans from time to time. A portion of one such revision is given in Fig. 2, where the broken contours show the lower portion of the fill, previously executed in accordance with the first plans, and the full contours indicate a method of completing the fill agreeably with less material than the original plan called for. Cross sections of this fill are shown in Fig. 4.

To the north of the shore road is a long mound to be planted with trees, as a screen to the private lands behind it, and the Stoneham Turnpike, running north and south along the west shore of the pond, is curved slightly where it is relocated upon the fill, to close the view of houses outside the reservation on the north and to fit the curve of the main driveway about the pond.

Opposite the western arm of the pond the Stoneham Turnpike ran over a causeway between the western arm of the pond and Dark Hollow Swamp. (See cross sections, Fig. 5.) It was thought that the extra capacity to be obtained by relocating the road along the west side of the swamp, clearing the swamp of peaty material, and joining it to the pond was not commensurate with the expense. The causeway was therefore raised and given greater breadth, an irregular outline and a slightly undulating profile, by means of the material excavated from the adjacent pond bottom. Such parts of the old surface as were high enough were saved, and the new surface adjusted to them. A sand beach was made on the side toward the pond. To avoid the unnatural look that land would have so much below the level of the pond and yet so close to it, to avoid the necessity of making the causeway impervious under the eight feet of head between the reservoir level and the swamp, and to secure an additional element of pond scenery, the swamp was flooded to the same level as the reservoir by means of a short, inconspicuous dam at a narrow point on the north, whence the overflow was carried by a ditch to Doleful Pond. Any one going south along the road sees first, on his right, a long view down Dark Hollow Pond, well terminated by Hound Rock. To his left the trees will block any view of Spot Pond. (See plan, Fig. 3.) When once down upon the level

FIG. 1. — TOP OF DIKE ACROSS BLACK BROOK VALLEY, LOOKING WEST.

FIG. 2. — FILL AND RELOCATED ROAD, NORTH OF BASKET COVE.

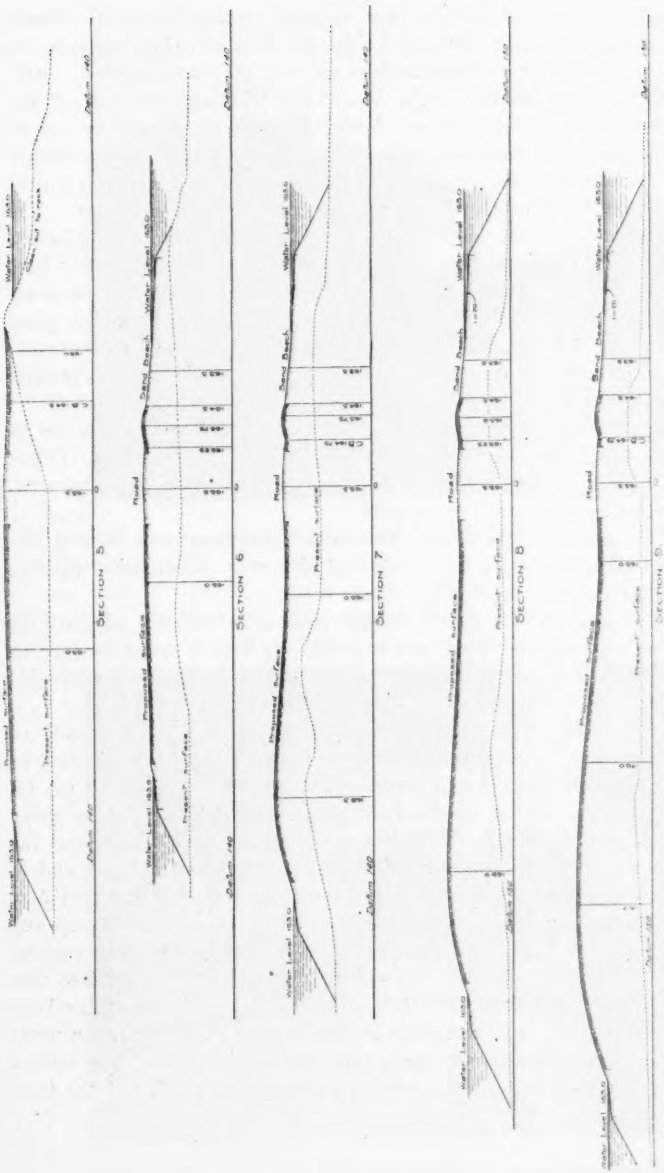

FIG. 5. — CROSS SECTIONS OF CAUSEWAY AT DARK HOLLOW POND.
Scale, 50 feet to an inch.

causeway, a fine diagonal view of Spot Pond, with Great Island, opens on the left, while on the right the trees will close in, preventing a distraction of attention between two points of interest. Still farther along the causeway, when Deer Hill begins to cut off the view of the pond, a nearer view of Hound Rock and the end of Dark Hollow Pond opens on the right, effectively framed with foliage.

At Mortar Cove, the extreme southern end of the pond, is a dike crossing the flat deposit of glacial *débris* which fills the valley. The southern gatehouse now stands on this dam. Several rounded hillocks, clothed with a good growth of oaks, rose above the necessary level of the dike. (See Plate V, Figs. 1 and 2.) There was no great surplus of fill to be had here owing to the deep water of the pond and the clean gravel bottom which did not need to be excavated. It was thus impracticable to conceal the valley below the pond level by any large amount of extra grading. The back of the fill is, therefore, to be planted thickly with trees, which will in time cut off any view from the road of the low ground to the south. (Plate VI, Fig. 1.) The surface is modeled to fit the projecting hillocks, saving as many trees as possible.

The swamp to the east of the southern gatehouse was treated like Dark Hollow Swamp and formed into a narrow pond, called Quarter-Mile Pond, with its overflow to the south.

The location of the road through the woods from the edge of the pond to Woodland Road was carefully studied, in order to save as many trees as possible along the roadside and secure an agreeable alignment. (See Plate VI, Fig. 2.)

The new pumping station is situated a short distance south of Pepe's Cove, where Spot Pond brook leaves the pond. A dam of considerable height was necessary here, but the valley to be cut off was narrow. At its northern end, this dam had to run into a rocky bank slanting steeply away from the pond. At its southern end the ground sloped away much more gently. To save material, and to harmonize with the steep northern bank, the northern landward face of the dam was given a steep slope. This became less steep and swung away from the pond to give room for the pumping station. To the south of the station the form of the dam blended into that of the adjacent hill. The station itself was set almost at the level of the top of the dam, though a little behind it. This has a great advantage, as seen from the other side of the pond. The station appears to be built on the natural shore of the pond, and the trees

FIG. 1. — HALF-MILE ROAD, LOOKING EAST FROM NEAR GATE HOUSE.

FIG. 2. — EXTENSION OF HALF-MILE ROAD, NEAR QUARTER-MILE POND.

FIG. 1. — GATE HOUSE AND BACK OF DIKE AT MORTAR COVE.

FIG. 2. — CONTINUATION OF HALF-MILE ROAD, NEAR WOODLAND ROAD.

behind it conceal the lower land behind the dam. If the station had been placed much below the top of the dam, only its upper story would be visible, thus betraying absolutely the fact that the pond was there held by a dike and giving the building a submerged appearance.

After the construction work which I have roughly indicated, there still remained the problem of planting, the main objects of which were to cover the bare surface of the hills, to block out objectionable views, to frame good views, and to provide shade along the roads. When this work is finished, the pond will be left to itself to gain, by time and natural foliage-growth, that beauty which no skill can give at once.

PROCEEDINGS.

DECEMBER MEETING.

YOUNG'S HOTEL,
BOSTON, December 12, 1900.

President Cook in the chair.

The following members and guests were present: —

MEMBERS.

L. M. Bancroft, James F. Bigelow, George Bowers, Dexter Brackett, E. C. Brooks, Fred Brooks, G. A. P. Bucknam, George F. Chace, L. Z. Carpenter, John C. Chase, Freeman C. Coffin, Byron I. Cook, Arthur W. Dean, W. W. DeBerard, John W. Ellis, John N. Ferguson, F. F. Forbes, William E. Foss, Frank B. French, Julius C. Gilbert, T. C. Gleason, Albert S. Glover, Amos A. Gould, J. A. Gould, Frank E. Hall, L. M. Hastings, T. G. Hazard, Jr., Horace G. Holden, John L. Howard, Willard Kent, James W. Locke, Cyrus M. Lunt, T. H. McKenzie, Frank E. Merrill, Leonard Metcalf, Frank L. Northrop, W. W. Robertson, Charles E. Riley, Charles W. Sherman, M. A. Sinclair, George A. Stacy, Frederic P. Stearns, William F. Sullivan, Robert J. Thomas, Harry L. Thomas, William H. Thomas, D. N. Tower, W. H. Vaughn, Charles K. Walker, George W. Travis, John C. Whitney, George E. Winslow.

ASSOCIATES.

Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; George E. Gilchrist, by E. C. Jacobs; Hersey Mfg. Co., by J. A. Tilden and Albert S. Glover; Henry F. Jenks; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Rensselaer Mfg. Co., by Fred S. Bates; Builders' Iron Foundry, by Frederick N. Connet; A. P. Smith Mfg. Co., by William H. Van Winkle; Sumner & Goodwin Co., by Frank E. Hall; Union Water Meter Co., by J. P. K. Otis, A. S. Otis, and F. N. Northrop; United States Cast Iron Pipe and Foundry Co., by John M. Holmes; R. D. Wood & Co., by E. F. Krewson.

GUESTS.

A. A. Knudson, New York; D. E. Makepeace and George H. Snell, Attleboro, Mass.; Fred V. Fuller, Boston, Mass.; Walter R. Carroll, Brookline, Mass.; Henry W. Lamb, Brookline, Mass.; George M. Nash, Everett, Mass.; Hon. M. R. Leonard, Waltham, Mass.

The Secretary read the following names of applicants for membership: —

For Resident Member.

John O. Hall, Mayor, Quincy, Mass.; George H. Snell, Superintendent of Water Works, Attleboro, Mass.

For Non-Resident Member.

J. William Griffin, Arlington, N. J.; Clinton S. Burns, C.E., Kansas City, Mo.

For Associate.

Harold L. Bond & Co., Construction Work Supplies, 140 Pearl Street, Boston; Lamb & Ritchie, Manufacturers of Tin-Lined Iron Pipe and Lead-Lined Iron Pipe, Cambridgeport.

The Secretary was instructed to cast the ballot of the Association in favor of the applicants named above, which he did, and they were declared elected to membership.

The President appointed as a Committee on Uniform Statistics, Messrs. Joseph E. Beals, of Middleboro; George F. Chace, of Taunton; and John C. Whitney, of Newton; and as a Committee on Standard Specifications for Cast-Iron Pipe, Messrs. Freeman C. Coffin, of Boston; Dexter Brackett, of Boston; and F. F. Forbes, of Brookline.

Mr. A. A. Knudson, Electrical Engineer, New York City, read a paper on "Electrolysis," which called forth discussion and inquiries by the President, and Messrs. Dexter Brackett, Theodore H. McKenzie, Cyrus M. Lunt, John C. Whitney, George E. Winslow, Charles K. Walker, John C. Chase, Frederic P. Stearns, G. H. Snell, Robert J. Thomas, T. C. Gleason, Freeman C. Coffin, Frederick Brooks, George A. Stacy, and F. N. Connet.

On motion of Mr. Brackett, the thanks of the Association were voted to Mr. Knudson for his very interesting and instructive paper.

Adjourned.

PROCEEDINGS.

ANNUAL MEETING.

YOUNG'S HOTEL,
BOSTON, January 9, 1901.

President Cook in the chair.

The following-named members and guests were present: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, Joseph E. Beals, George Bowers, E. C. Brooks, Frederick Brooks, George F. Chace, John C. Chase, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, A. O. Doane, William Downey, F. F. Forbes, William E. Foss, D. H. Gilderson, Albert S. Glover, E. H. Gowing, Frank E. Hall, John O. Hall, L. M. Hastings, T. G. Hazard, Jr., Horace G. Holden, John L. Howard, H. R. Johnson, Willard Kent, C. F. Knowlton, A. E. Martin, Thomas Naylor, Frank L. Northrop, Edward L. Peene, J. B. Putnam, W. W. Robertson, C. E. Riley, H. E. Royce, W. J. Sando, Charles W. Sherman, George H. Snell, R. J. Thomas, H. L. Thomas, William H. Thomas, William W. Wade, Charles K. Walker, G. W. Travis, J. A. Welch, Frank B. Wilkins, C.-E. A. Winslow, George E. Winslow.

ASSOCIATES.

The George F. Blake Mfg. Co., by George J. Foran; Harold L. Bond & Co., by Mr. Bond; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Henry F. Jenks; Sumner & Goodwin Co., by Frank E. Hall; Union Water Meter Co., by Frank L. Northrop.

HONORARY MEMBERS.

George H. Frost, Henry C. Meyer.

GUESTS.

J. M. Anderson and M. F. Brennan, Boston, Mass.; George H. Palmer, City Engineer, Palmer, Mass.; John H. Cook, Paterson, N. J.; Charles A.

Claflin, Boston, Mass.; Fred Crosby, Montgomery, Ala.; J. J. Moore, Hingham, Mass.; S. L. Chadbourne, Yonkers, N. Y.; Dr. John H. Washburn, President Rhode Island State College, Kingston, R. I.

The President, in accordance with the provisions of the constitution, declared the polls closed for the election of officers for the ensuing year, and appointed Messrs. Chace, of Taunton, and Winslow, of Waltham, tellers to assort and count the ballots and declare the result.

The following-named were elected to membership: —

Resident Members.

Charles B. Parker, Assistant Superintendent, Cambridge; J. William Kay, Superintendent, Milford; William E. Mayberry, Superintendent, Braintree; J. M. Anderson, Foreman, City Water Department, Worcester; Edward M. Shedd, Inspector, Somerville.

Non-Resident Member.

Charles F. Loweth, Consulting Civil Engineer, St. Paul, Minn.

Associate.

Charles A. Claflin, of Charles A. Claflin & Co., Boston, Steam Engineering and Water-Works Supplies.

REPORT OF THE SECRETARY.

The Secretary, Mr. Willard Kent, submitted the following report, which, on motion of Mr. Coggeshall, was received and ordered to be spread upon the record.

To the President and Members of the New England Water Works Association: — I submit herewith a summary of statistics relating to membership, receipts, and expenditures for the seven months ending December 31, 1901.

SUMMARY OF STATISTICS RELATING TO MEMBERSHIP.

June 1, 1900. Total membership 594

ACTIVE MEMBERS.

June 1, 1900.	Total active membership		519	
	Withdrawals:			
	Resignations	8		
	Dropped	1		
	Died	2	11	
			508	
	Initiations:			
	June	4		
	September	9		
	November	5		
	December	4	22	530

HONORARY MEMBERS.

June 1, 1900.	Honorary members		5	
	Died		1	4

ASSOCIATES.

June 1, 1900.	Total associate membership		70	
	Withdrawals:			
	Died		1	
			69	
	Initiations:			
	June	1		
	December	2	3	72
January 1, 1901.	Total membership			606
	Net gain in membership			12

SUMMARY OF RECEIPTS FROM JUNE 1, 1900, TO JANUARY 1, 1901.

Balance from former Secretary	$612.49
Initiations	98.00
Subscriptions and sale of JOURNALS	155.70
Advertisements	880.00
Dues	1 219.75
Sundry	132.18
	$3 098.12

SUMMARY OF EXPENSES FROM JUNE 1, 1900, TO JANUARY 1, 1901.

Rent	$300.00
Junior Editor	250.00
Assistant Secretary	200.00
Secretary	166.67

Stenographer (reporting meetings)	$119.35
June excursion	94.50
Stereopticon	53.91
Music	40.00
Badges	31.60
Expenses of Committee on Exhibit of Associate Members	25.50
JOURNAL	1 252.21
Printing, stationery, postage, express, and sundry incidentals	294.47
	$2 828.21

Respectfully submitted,

WILLARD KENT, *Secretary.*

REPORT OF THE TREASURER.

The Treasurer, Mr. Bancroft, submitted the following report, which was received and placed on file : —

LEWIS M. BANCROFT, TREASURER,

In account with New England Water Works Association.

RECEIPTS.

1900.			
June 1.	Balance on hand		$1 270.40
9.	Received of Willard Kent, Sec'y	$154.90	
16.	" " " " "	564.55	
25.	" " " " "	162.75	
July 9.	" " " " "	110.00	
24.	" " " " "	198.00	
August 22.	" " " " "	210.75	
September 11.	" " " " "	193.38	
13.	" " " " "	612.49	
	" " " " "	50.75	
October 8.	" " " " "	164.75	
20.	" " " " "	197.75	
November 7.	" " " " "	171.15	
26.	" " " " "	151.50	
December 19.	" " " " "	155.40	3 098.12
	Received interest on deposit, People's Savings Bank, Worcester		65.67
			$4 434.19

EXPENDITURES.

1900.		
June 7.	Willard Kent, salary and expenses	$64.50
11.	Charles W. Sherman, salary and expenses	89.50
	Evening Post, electrotype	.50
14.	John Chamberlain, floral tribute late J. C. Haskell	10.00
25.	L. M. Bancroft, revenue stamps	2.48
	Boston Society Civil Engineers, rent to June 1	100.00
	J. M. Ham, salary to June 15, stamps and express	28.92
	Samuel Usher, printing JOURNAL	309.50
26.	C. H. Curtis, caterer	44.50
July 10.	Samuel Hobbs & Co., stationery	3.92
25.	J. M. Ham, salary to July 15, express, etc.	26.28
August 23.	P. S. Keating, barges, June meeting	50.00
	Samuel Usher, printing	7.25
September 6.	American Society Civil Engineers, binding	2.40
	Charles W. Sherman, salary and expenses to September 1	83.06
	Boston Society Civil Engineers, rent to September 1	100.00
	W. T. Almy, badges	31.60
	Willard Kent, salary and expenses to September 1	85.00
10.	J. M. Ham, salary and expenses to August 15	28.33
29.	Henry F. Jenks, expenses committee on exhibits at nineteenth annual convention	25.50
	Thomas P. Taylor, stereopticon, nineteenth annual convention	33.91
October 9.	J. M. Ham, salary to September 15, expenses nineteenth annual convention	50.25
	W. N. Hughes, printing	1.75
	Samuel Usher, printing JOURNAL and Constitution	392.30
25.	D. Gillies' Sons, printing	55.50
	J. M. Ham, salary to October 15	25.00
November 9.	Bacon & Burpee, report of September meeting	91.85
	D. Gillies' Sons, printing	32.25
19.	Tremont Temple, directory card	.35
	W. N. Hughes, numbering machine	12.00
	Willard Kent, rebate to J. C. Whitney, for sundry payments	14.00
	Francis L. Pratt, music, November meeting	20.00
27.	Hub Engraving Co., plates	57.03
30.	Joseph E. Beals, services and expenses, Senior Editor	40.00
	J. M. Ham, salary to November 15, postage and express	29.85

	Thomas P. Taylor, stereopticon	$10.00
December 17:	D. Gillies' Sons, printing	54.00
	Charles W. Sherman, salary to December 1, postage and express	84.05
	Willard Kent, salary to December 1, postage and express	69.34
18.	Francis L. Pratt, music, December meeting	20.00
	Boston Society Civil Engineers, rent to December 1	100.00
21.	J. M. Ham, salary and express	27.25
	Thomas P. Taylor, stereopticon	10.00
	Samuel Hobbs & Co., stationery	2.03
		$2 325.95

BALANCE ON HAND.

Deposit, People's Savings Bank, Worcester	$1 249.70	
Deposit, First National Bank, Reading	858.54	2 108.24
		$4 434.19

LEWIS M. BANCROFT, *Treasurer.*

READING, January 1, 1901.

John H. Washburn, Ph.D., President of the Rhode Island College of Agriculture and Mechanic Arts, gave an interesting talk on "Some of the Physiographic Features which affect our Water Supply," illustrated by a large number of lantern slides.

Mr. W. J. Sando, Manager International Steam Pump Co., Brooklyn, N. Y., contributed a paper descriptive of the Metropolitan Water Works Pumping Machinery.

Mr. Chace, for the committee to assort and count the ballots for officers for the ensuing year, made the following report: —

For President.

F. H. CRANDALL, Burlington, Vt. 159

For Vice-Presidents.

CHARLES K. WALKER, Manchester, N. H. 157
JAMES BURNIE, Biddeford, Me. 145
WILLIAM E. HAWKS, Bennington, Vt. 147
F. E. MERRILL, Somerville, Mass. 152
T. G. HAZARD, Jr., Narragansett Pier, R. I. 145
CHARLES E. CHANDLER, Norwich, Conn. 144

For Secretary.

WILLARD KENT, Narragansett Pier, R. I. 160

For Treasurer.

L. M. BANCROFT, Reading, Mass. 161

For Editor.

C. W. SHERMAN, Boston, Mass. 160

For Advertising Agent.

R. J. THOMAS, Lowell, Mass. 157

For Additional Members of Executive Committee.

P. KIERAN, Fall River, Mass. 151
GEORGE A. STACY, Marlboro, Mass. 152
D. N. TOWER, Cohasset, Mass. 147

For Finance Committee.

A. W. F. BROWN, Fitchburg, Mass. 157
W. F. CODD, Nantucket, Mass. 156
J. W. CRAWFORD, Lowell, Mass. 154

Total ballot	161
Blanks	2
	163

On motion of Mr. Thomas, of Lowell, the thanks of the meeting were voted to Dr. Washburn and to Mr. Sando for their able, interesting, and instructive papers.

Adjourned.

PROCEEDINGS.

FEBRUARY MEETING.

YOUNG'S HOTEL,
BOSTON, February 13, 1901.

President Crandall in the chair.

The following members and guests were in attendance: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, Joseph E. Beals, George Bowers, Roland Barnes, Fred. Brooks, George Cassell, George F. Chace, G. L. Chapin, John C. Chase, William F. Codd, Freeman C. Coffin, F. H. Crandall, Arthur W. Dean, John W. Ellis, B. R. Felton, F. F. Forbes, Frank L. Fuller, Frank E. Fuller, William E. Foss, E. V. French, Julius C. Gilbert, J. F. Gleason, Albert S. Glover, William R. Groce, Frank E. Hall, J. C. Hammond, Jr., John O. Hall, L. M. Hastings, T. G. Hazard, Jr., Horace G. Holden, Willard Kent, James W. Locke, C. F. Knowlton, Frank E. Merrill, Leonard Metcalf, H. N. Parker, J. B. Putnam, W. W. Robertson, William T. Sedgwick, P. P. Sharples, Charles W. Sherman, Sidney Smith, John D. Shippee, George A. Stacy, George H. Snell, Robert J. Thomas, William H. Thomas, W. F. Sullivan, W. H. Vaughn, W. W. Wade, C.-E. A. Winslow, C. K. Walker, John C. Whitney.

ASSOCIATES.

Harold L. Bond & Co., by Mr. Bond; Chadwick Lead Works, by A. H. Broderick; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Charles A. Claflin & Co., by Mr. Claflin; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Henry F. Jenks; Lead Lined Iron Pipe, by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin and Charles H. Baldwin; Neptune Meter Co., by H. H. Kinsey; Lamb & Ritchie, by George M. Nash; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; Builders Iron Foundry, by W. C. Buell; Sumner & Goodwin Co., by Frank E. Hall; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by J. K. P. Otis and Frank L. Northrop; United States Cast Iron Pipe & Foundry Co., by John M. Holmes; R. D. Wood & Co., by E. F. Krewson.

GUESTS.

J. F. Carmichael, Lowell, Mass.; Julian P. Wood, Marlboro, Mass.; Thomas H. Naughton, Somerville, Mass.; George E. Hersey, Superintendent, Whitman, Mass.; Amos H. Eaton, Chr., Middleboro, Mass.; Mr.

Edwards, Londonderry, N. S.; Prof. W. H. Niles, Boston, Mass.; George W. Babcock, Assistant Superintendent, Attleboro, Mass.; Prof. W. M. Davis, Cambridge, Mass.; Dr. George W. Field, Massachusetts Institute of Technology, Boston, Mass.; A. D. Flinn, Boston, Mass.; Fred A. Beals, Everett, Mass.; Macy S. Pope and E. P. Walters, Boston, Mass.; A. C. Grover, City Engineer, Rutland, Vt.

The following applications were received, having been approved by the Executive Committee: —

For Resident Member.

Charles N. Taylor, C.E., Wellesley, Mass.

For Associate.

Barr Pumping Engine Co., Philadelphia, Pa.

On motion, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and they were declared elected.

Mr. William R. Groce called the attention of members to House Bill No. 498, "To provide that unpaid water rates shall be a lien upon the estate," now before the Massachusetts legislature, and to the fact that there would be a hearing upon this bill before the Committee on Judiciary of the Legislature on February 15 at the State House.

Prof. William T. Sedgwick, Professor of Biology, Massachusetts Institute of Technology, presented a paper entitled "The Rise and Development of Water Supply Sanitation in the Nineteenth Century," which was discussed by Messrs. George F. Chace and E. V. French.

A paper on "The Causes of Rainfall" was presented by Prof. W. M. Davis, of Harvard College, and was discussed by Prof. William H. Niles, of the Massachusetts Institute of Technology, and Messrs. George F. Chace, Charles W. Sherman, Fred. Brooks, Charles K. Walker, John C. Chase, Sidney Smith, and J. C. Hammond, Jr.

Discussion on the subject of "Charges for Private Fire Service" was opened by Mr. J. C. Hammond, Jr., and was continued by Messrs. Charles K. Walker and E. V. French. Further discussion on this topic was postponed until the next meeting.

Adjourned.

OBITUARY.

Mellen S. Harlow, who was elected to Associate membership in this Association on December 11, 1895, died at Faulkner, Mass. December 29, 1900.

New England

Water Works Association

ORGANIZED JUNE 21, 1882.

CONSTITUTION

AND

LIST OF MEMBERS.

MARCH, 1901.

BOSTON, MASS.:
W. N. HUGHES, 52 PURCHASE ST.
1901.

PRESIDENTS

OF THE

New England Water Works Association.

*James W. Lyon, 1882–83.

Frank E. Hall, 1883–84.

George A. Ellis, 1884–85.

Robert C. P. Coggeshall, 1885–86.

Henry W. Rogers, 1886–87.

*Edwin Darling, 1887–88.

*Hiram Nevons, 1888–89.

Dexter Brackett, 1889–90.

*Albert F. Noyes, 1890–91.

Horace G. Holden, 1891–92.

George F. Chace, 1892–93.

George E. Batchelder, 1893–94.

George A. Stacy, 1894–95.

Desmond FitzGerald, 1895–96.

*John C. Haskell, 1896–97.

Willard Kent, 1897–98.

Fayette F. Forbes, 1898–99.

Byron I. Cook, 1899–1900.

Frank H. Crandall, 1901.

* Deceased.

CONSTITUTION OF

The New England Water Works Association,

Adopted September 19, 1900.

ARTICLE I.

NAME AND OBJECT.

SECTION 1. The name of this society shall be THE NEW ENGLAND WATER WORKS ASSOCIATION.

SECT. 2. Its objects shall be the advancement of knowledge relating to water works and water supply, and the encouragement of social intercourse among water works men.

ARTICLE II.

SECTION 1. The membership of the Association shall consist of Members, Honorary Members, and Associates.

SECT. 2. Water works superintendents or other executive officers, commissioners or members of Water Boards, hydraulic engineers, sanitarians or other persons qualified to aid in the advancement of knowledge relating to hydraulic questions, shall be eligible as Members.

SECT. 3. Members only shall be eligible to office and entitled to the right to vote.

SECT. 4. Associates shall be firms or representatives of firms engaged in dealing in supplies used by water works.

SECT. 5. Members hereafter elected engaging in the business of furnishing water works supplies shall cease to be Members of the Association and their names shall be transferred to the list of Associates.

SECT. 6. Associates shall be entitled to representation at each meeting of the Association, but shall not be entitled to vote or take part in any discussion unless permission is given by the meeting.

SECT 7. Honorary Members shall be men eminent in some line of work connected with hydraulic engineering or water supply.

SECT. 8. Members shall be classed as Resident or Non-Resident; the former comprising residents of the New England States, all others being Non-Resident Members.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

SECTION 1. An application for admission to the Association as Member or Associate shall embody a concise statement of the candidate's qualifications for membership, and shall be endorsed by two Members of the Association.

SECT. 2. Applications for membership shall be considered by the Executive Committee, who shall present them to the Association for ballot, provided a majority are in favor of such action.

SECT. 3. Election to membership shall be by ballot, and shall require two-thirds of the ballots cast.

SECT. 4. Members and Associates elect shall subscribe their names to the Constitution by signing a form to be furnished by the Secretary.

SECT. 5. Any person who shall be in arrears to the Association for two years' dues shall be notified by the Secretary that if payment is not made within three months his name will be dropped from the roll; and if such arrears are not paid within the time specified, the Secretary shall erase the name from the membership list.

SECT. 6. A member of any grade may withdraw from the Association by giving written notice to the Secretary and settling all indebtedness to the Association.

SECT. 7. A member of any grade may be expelled from the Association upon the recommendation of the Executive Committee, adopted by a two-thirds vote of the members present and voting at any regular meeting.

ARTICLE IV.

DUES.

SECTION 1. The Initiation Fee shall be

For Resident Members	$5 00
For Non-Resident Members	3 00
For Associates	10 00

SECT. 2. The Annual Dues shall be

For Members	$3 00
For Associates	15 00

which shall include a subscription to THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

SECT. 3. A person transferred from the grade of Member to that of Associate shall not be assessed an additional initiation fee, but shall be liable for dues as an Associate.

ARTICLE V.

OFFICERS.

SECTION 1. The officers of this Association shall be a President, six Vice-Presidents, not more than three of whom shall be residents of the same State, a Secretary, and a Treasurer; these, together with the Editor and Advertising Agent of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION and three other members, shall constitute the Executive Committee, in whom the government of the Association shall be vested.

SECT. 2. The term of office of all officers and committees shall be one year, but shall continue until their successors are duly elected.

SECT. 3. There shall also be a Finance Committee of three Members of the Association other than members of the Executive Committee.

SECT. 4. All officers and Committees shall assume their duties immediately after the close of the meeting at which they have been elected.

ARTICLE VI.

DUTIES OF OFFICERS.

SECTION 1. The President shall have a general supervision of the affairs of the Association. He shall preside at meetings of the Asso-

ciation and of the Executive Committee. In case of his absence or a vacancy in his office, the Vice-Presidents in order of seniority shall discharge his duties.

Sect. 2. The Executive Committee shall have full control of the management of the Association, subject to the action of the Association at any meeting. They shall make the necessary arrangements for all meetings, and shall have power to expend the funds of the Association, provided that no indebtedness shall be incurred in excess of the funds in the hands of the Treasurer. All questions in Executive Committee shall be decided by a majority vote, and six members shall be a quorum. The Executive Committee shall hold meetings at the call of the President, or, in his absence or inability to serve, at the call of the senior Vice-President.

Sect. 3. The Secretary shall conduct the official correspondence of the Association, shall collect and receipt for all fees and dues, and transmit the same to the Treasurer quarterly, taking his receipt therefor; he shall issue notices of all meetings of the Association at a date not less than two weeks prior to the time appointed for such meetings. He shall make a report to the Association at the annual meeting of the general condition of the Association and especially of changes in the membership.

Sect. 4. The Treasurer shall receive from the Secretary all moneys collected by him for the Association, giving his receipt therefor, and shall pay all demands against the Association when approved by the President. He shall keep a proper account of all receipts and expenditures, and shall make a report to the Association, at the annual meeting, of his doings as Treasurer during the year preceding, together with a statement of the financial standing of the Association.

Sect. 5. The Finance Committee shall meet on or before the day of the annual meeting and shall audit the accounts of the Secretary and Treasurer. They shall hold such other meetings as the interests of the Association may require.

Sect. 6. The proceedings of the Association shall be published as THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, which shall be issued quarterly, under the direction of a Board of Editors, consisting of the President and Secretary, *ex-officiis*, and the Editor and Advertising Agent chosen by ballot. The Journal shall contain such portion of the record of any meeting as the Board

of Editors may deem it expedient to publish, as well as any other articles which they shall consider of interest to the Association.

SECT. 7. The Editor of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION shall, under the direction of the Board of Editors, keep and prepare for publication all matters intended to be printed in the Journal, and shall act as the executive officer of the Board of Editors. He shall present a report at the annual meeting, showing in detail the cost of publication of the Journal and the receipts from advertising and subscriptions.

ARTICLE VII.

NOMINATION AND ELECTION OF OFFICERS.

SECTION 1. At the business meeting during the annual convention the Associaton shall elect or appoint, in such manner as may be approved by the meeting, a Nominating Committee of five members, who shall present a report before the first day of November in the form of a list of nominations for officers for the ensuing year. This report shall be printed and mailed by the Secretary to the membership of the Association.

SECT. 2. At any time before December 1, any ten or more Members of the Association may send to the Secretary additional nominations signed by such Members.

SECT. 3. The Secretary shall issue a printed ballot on the fifteenth day of December, which shall contain the nominations made by the Nominating Committee and such other nominations as may have been received by him in accordance with Section 2. This ballot shall be mailed to all members entitled to vote.

SECT. 4. Ballots may be sent by mail to the Secretary or handed to him directly. They must be enclosed in two sealed envelopes, and the outer envelope shall be endorsed by the voter's signature.

SECT. 5. The polls shall be closed one hour after the time of opening the Annual Meeting, and the ballots shall be canvassed by tellers appointed by the presiding officer. The persons receiving the highest number of votes for the offices for which they are candidates shall be declared elected.

ARTICLE VIII.

MEETINGS.

SECTION 1. A Convention of the Association for the reading and discussion of papers and for social intercourse shall be held annually

at such time and place as may be determined by the Executive Committee.

SECT. 2. There shall be two general business meetings of the Association each year; first, the annual meeting, which shall be held in Boston on the second Wednesday in January, and at which the annual reports for the year ending December 31 shall be presented, and the ballot for officers canvassed; and second, a business meeting during the annual convention.

SECT. 3. In addition to the above, business meetings shall be held on the second Wednesday of the months of November, December, February and March, and, at the discretion of the Executive Committee, in June.

SECT. 4. At any business meeting of the Association, twenty members shall constitute a quorum.

SECT. 5. All regular meetings of the Association, except the annual convention, shall be held in Boston, unless otherwise voted by the Executive Committee.

SECT. 6. Special meetings of the Association may be held at the call of the President. At special meetings no applications for membership shall be considered, and no business shall be transacted, unless announced in the call for the meeting and on the recommendation of the Executive Committee.

SECT. 7. Meetings of the Executive Committee shall be held before each business meeting of the Association and at such other times as the President may deem necessary.

ARTICLE IX.

AMENDMENTS.

SECTION 1. Proposed amendments to this Constitution must be submitted in writing to the Executive Committee, and shall be presented to the Association at a regular meeting, if so decided by vote of the committee. It shall be the duty of the Executive Committee to bring before the Association any proposed amendment at the written request of ten members.

SECT. 2. Announcements of a proposed amendment which is recommended by the Executive Committee, or by ten members of the Association, shall be given by printing the amendment in the notices of the regular meeting. A two-thirds vote of the members present and voting shall be necessary for the adoption of an amendment.

LIST OF MEMBERS,

WITH ADDRESS AND DATE OF ELECTION.

NAME.	Date of Election.
Abbot, Everett L. 236 Eighth Avenue, New York City.	June 9, 1892
Adams, John D. Supt. Water Works, Provincetown, Mass.	Sept. 8. 1897
Allen, Charles A., C. E. 44 Front St., Rooms 109-110, Worcester, Mass.	June 16, 1886
Allen, Charles F. Treasurer Water Company, Hyde Park, Mass.	June 16, 1886
Allis, Solon M., C. E. 43 James Street, Malden, Mass.	June 17, 1887
Amos, E. C. 51 Montreal Street Railway Bldg., Montreal, Can.	Nov. 14, 1900
Amyot, John A., M. B. Bacteriologist to the Provincial Board of Health of Ontario, 305 Joseph St., Toronto, Canada.	Nov. 14, 1900
Armstrong, S. G., C. E. Care F. W. Waldron, C. E., Amilanda, Upper Buitenkant St., Cape Town, South Africa.	Feb. 13, 1895
Anderson, J. M. 246 Pleasant St., Worcester, Mass.	Jan. 9, 1901
Andrews, Frank A. Assistant Supt. Pennichuck Water Works, Nashua, N. H.	Dec. 14, 1887
Appleton, Francis E. Paymaster Locks & Canals Co., Lowell, Mass.	Dec. 8, 1897
Babbidge, P. F. Supt. Water Works, Keene, N. H.	Feb. 12, 1890
Babcock, Stephen E. Water Works and Hydraulic Engineer, Little Falls, N. Y.	June 12, 1886

NAME.	Date of Election.
Bacot, R. C., Jr. Supt. Meter Dept., P. O. Box 221, Port Chester, N. Y.	Dec. 12, 1888
Badger, Frank S. Room 24, 35 Wall St., New York City.	June 10, 1896
Badger, Wm. E. Assistant Engineer, Locks & Canals Co., Lowell, Mass.	June 14, 1899
Bagnell, Richard W. Supt. Water Works, Plymouth, Mass.	Dec. 21, 1882
Bailey, E. W. City Engineer, Somerville, Mass.	Dec. 11, 1895
Bailey, Frank S. State Board of Health, State House, Boston, Mass.	Sept. 8, 1897
Bailey, George I. Supt. Bureau of Water, 300 Western Avenue, Albany, N. Y.	Dec. 14, 1892
Baldwin, Charles H. 159 Franklin St., Boston, Mass.	June 17, 1887
Baldwin, Richard Proprietor Water Works, Terryville, Conn.	June 10, 1891
Bancroft, Lewis M. Supt. Water Works, Reading, Mass.	Jan. 8, 1890
Barbour, Frank A., C. E. 1120 Tremont Building, Boston, Mass.	Jan. 10, 1894
Barnes, Roland D., C. E. 23 Spring Street, Malden, Mass.	June 14, 1899
Barrett, Albert P. Woburn, Mass.	March 12, 1890
Barrus, George H. Consulting Steam Engineer, 12-20 Pemberton Bldg.. Pemberton Sq., Boston, Mass.	Jan. 14, 1891
Bartlett, Charles H., C. E. 9 Concord Square, Boston, Mass.	Feb. 8, 1893
Bartlett, R. S. Supt. Water Works, Norwich, Conn.	Jan. 13, 1897
Bassett, Carroll Ph. Treasurer Water Co., Summit, N. J.	June 13, 1889

NAME.	Date of Election.
Bassett, Geo. B., C. E. 363 Washington St., Buffalo, N. Y.	Sept. 10, 1897
Batchelder, George W. Water Registrar, Worcester, Mass.	June 14, 1899
Batcheller, Francis Water Commissioner, No. Brookfield, Mass.	Jan. 10, 1894
Bates, Oren B. Clinton, Mass.	Sept. 11, 1895
Bates, Hon. Theodore C. 29 Harvard St., Worcester, Mass.	Jan. 10, 1894
Battles, James M. 120 Marginal St., cor. Cottage St., East Boston, Mass.	June 21, 1882
Beals, Joseph E. Supt. Water Works, Middleboro, Mass.	June 16, 1886
Beasom, C. B., C. E. 248 Tremont St., Newton, Mass.	Dec. 12, 1894
Bennett, Thomas H. Supt. Water Works, Oswego, N. Y.	March 14, 1900
Benzenberg, G. H. Milwaukee, Wis.	June 9, 1892
Berkey, John A. Pres. Electric & Water Company, Little Falls, Minn.	Feb. 8, 1893
Bettes, Charles R. Chief Engineer, Queen's County Water Co., Far Rockaway, N. Y.	Dec. 9, 1896
Bigelow, James F. City Engineer, Marlboro, Mass.	Sept. 11, 1895
Birkinbine, Henry Hydraulic Engineer, 124 East Market Street, York, Pa.	June 17, 1887
Bisbee, Forrest E. Supt. Water Works, Auburn, Maine.	Sept. 11, 1895
Bishop, George H., C. E. 129 Main St., Middletown, Conn.	June 16, 1886
Bishop, Watson L. Supt. Water Works, Dartmouth, N. S.	March 8, 1893

NAME.	Date of Election.
Blackmer, James W., 2d Supt. Water Works, Beverly, Mass.	March 8, 1899
Bliss, Gerald M., C. E. 393 Warren Ave., Chicago, Ill.	Feb. 12, 1896
Blossom, William L., C. E. 355 Washington St., Brookline, Mass.	Dec. 13, 1893
Boggs, Edward M. Consulting, Civil and Hydraulic Engineer, 534 Stimpson Block, Los Angeles, Cal.	Dec. 11, 1889
Bowers, George City Engineer, Lowell, Mass.	March 9, 1892
Brackett, Dexter Engineer Distribution Dept., Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Bradley, R. H. Supt. Water Works, Le Sueur, Minn.	Dec. 14, 1892
Brinsmade, Daniel S. President and Engineer Ousatonic Water Co. Birmingham, Ct.	Sept. 19, 1883
Broatch, J. C. Supt. Water Works, Middletown, Conn.	April 21, 1885
Brooks, Edwin C. Supt. Water Works, Cambridge, Mass.	Feb. 10, 1897
Brooks, Fred 31 Milk Street, Boston, Mass.	Feb. 8, 1899
Brown, A. W. F. Water Registrar, Fitchburg, Mass.	June 17, 1887
Brown, Edward H. Supt. and Treas. Nevada County N. G. R. R. Grass Valley, Cal.	June 16, 1886
Brown, J. Henry 3 Tremont St., Charlestown, Mass.	Sept. 19, 1883
Brown, Walter I. Water Registrar, Bangor, Me.	June 11, 1896
Brownell, Ernest H., C. E. Brownell Block, 107 Westminster St., Providence, R. I.	Jan. 11, 1893
Bryant, C. B. City Engineer, Martinville, Va.	June 10, 1886

NAME.	Date of Election.
Bucknam, George A. P. Supt. Water Works, Norwood, Mass.	June 10, 1891
Burke, James E. Sec'y, Treas., and Supt. Princeton Water Co., Princeton, N. J.	Sept. 11, 1895
Burley, Harry B. 31 Milk Street, Room 55, Boston, Mass.	Dec. 14, 1892
Burnham, Albert S. Supt. Water Company, Revere, Mass.	June 13, 1888
Burnie, James Supt. Water Company, Biddeford, Me.	June 11, 1890
Burns, James Lynn, Mass.	Sept. 13, 1899
Burns, Clinton S. 409 Postal-Telegraph Bldg., Kansas City, Mo.	Dec. 12, 1900
Burr, William H. Prof. of Civil Engineering, Columbia University, and Consulting Engineer, New York City.	Feb. 16, 1894
Burse, A. H. Supt. Water Works, Pittsfield, Me.	Sept. 16, 1898
Bush, Edward W., C. E. Ætna Life Building, Hartford, Conn.	Feb. 13, 1895
Butler, J. Allen Supt. Portland Water Company, Portland, Conn.	June 10, 1891
Cairns, R. A. City Engineer, Waterbury, Conn.	Feb. 13, 1895
Card, Huber D. City Engineer, Willimantic, Conn.	Jan. 8, 1896
Carpenter, L. Z. Attleboro, Mass.	Dec. 13, 1899
Carroll, Fred B. Rumford Falls, Me.	Dec. 12, 1888
Cassell, George Supt. Water Works, Chelsea, Mass.	March 8, 1899

NAME.	Date of Election.
Caulfield, John Sec'y Water Works, St. Paul, Minn.	Dec. 8, 1897
Cavanagh, John T. Quincy, Mass.	Feb. 8, 1893
Chace, George F. Supt. Water Works, Taunton, Mass.	June 13, 1888
Chadbourne, E. J. Supt. Water Company, Wakefield, Mass.	June 18, 1885
Chairman of Water Commission. Watertown, Mass.	Feb. 14, 1900
Chandler, Charles E. City Engineer, 161 Main St., Norwich, Conn.	June 17, 1887
Chandler, Prof. Charles F. 51 East 54th St., New York City.	Dec. 12, 1888
Chapin, G. L. Water Commissioner, Lincoln, Mass.	March 10, 1897
Chapman, Benjamin R. Assistant Engineer, Brockton, Mass.	Feb. 9, 1898
Chase, John C. Chief Engineer Water Works Company, Derry, N. H.	June 19, 1884
Clapton, William Supt. Water Company, Newtown, N. Y.	Sept. 11, 1895
Clapp, Sidney K. 1 Ashburton Place, Boston, Mass.	Jan. 10, 1900
Clark, D. W. President Water Company, Portland, Me.	June 12, 1890
Clark, S. Frederic Water Commissioner, North Billerica, Mass.	March 8, 1899
Clark, Frederick W. Clerk Chestnut Hill Reservoir, Metropolitan Water Works, Brighton, Mass.	Jan. 11, 1893
Clark, Harry W. Chemist, Mass. State Board of Health, State House, Boston, Mass.	March 14, 1894
Clarke, E. W. Asst. Engineer, Rapid Transit R.R. Commission, 13 Astor Place, New York City.	Jan. 10, 1894

NAME.	Date of Election.
Cleveland, W. F. Sewer Commissioner, Brockton, Mass.	June 9, 1892
Cochran, Robert L. Supt. Water Works, Nahant, Mass.	June 16, 1886
Codd, William F. Supt. Water Company, Nantucket, Mass.	June 21, 1885
Coffin, Freeman C. Civil and Hydraulic Engineer, 53 State Street, Boston, Mass.	Feb. 13, 1889
Coggeshall, R. C. P. Supt. Water Works, New Bedford, Mass.	June 21, 1882
Cole, D. W. Box 696, Thomaston, Conn.	March 14, 1900
Cole, F. M. Meter Inspector, Brockton Water Works, Brockton, Mass.	Feb. 10, 1897
Collins, Lewis P. Lawrence, Mass.	Dec. 12, 1894
Colson, Charles D. Water Commissioner, Holyoke, Mass.	March 9, 1898
Connell, Michael A. Supt. Water Works, St. Hyacinthe, P. Q.	Dec. 13, 1893
Cook, Byron I. Supt. Water Works, Woonsocket, R. I.	March 13, 1889
Cook, Henry A. Supt. Water Works, Salem, Mass.	Feb. 10, 1892
Cram, Arthur N. Water Commissioner, Walpole, Mass.	March 11, 1896
Crandall, F. H. Supt. and Treas. Water Works, Burlington, Vt.	June 13, 1888
Crandall, George K. Civil Engineer, New London, Conn.	June 9, 1892
Crawford, J. W. Clerk Water Board, Lowell, Mass.	June 12, 1896
Crilly, P. F. Supt. Water Works, Woburn, Mass.	March 12, 1890

NAME.	Date of Election.
Croes, J. J. R., C. E. 68 Broad Street, Morris Building, N. Y. City.	June 17, 1887
Crowell, George E. President Water Works, Brattleboro, Vt.	June 15, 1893
Crosby, Everett U. 54 William Street, New York City.	March 4, 1900
Cuddeback, Allan W. Asst. Engineer Passaic Water Company, 109 Washington St., Paterson, N. J.	Jan. 10, 1900
Curtis, George D. 75 Tonawanda St., Dorchester, Mass.	Sept. 19, 1900
Cushing, Lucas Box 108, Mansfield, Mass.	Dec. 12, 1888
Daboll, L. E., C. E. New London, Conn.	Jan. 10, 1894
Danforth, John L. Gen. Supt. Spring Water Company, Kane, Pa.	Sept. 10, 1897
Davis, F. A. W. Vice Pres. and Treas. Water Co., Indianapolis, Ind.	June 17, 1887
Davis, Henry L. Supt. Water Works, Wallingford, Conn.	Jan. 12, 1898
Davis, J. M. Rutland, Vt.	Sept. 13, 1895
Davis, William E. Supt. Water Works, Sherburne, N. Y.	Dec. 11, 1889
Davison, George S. Sec. and Gen. Manager Monongahela Street Railway Co., 512 Smithfield St., Pittsburg, Pa.	June 15, 1894
Dean, Arthur W. City Engineer, Nashua, N. H.	March 8, 1899
Dean, Francis W. Mechanical Engineer, 53 State St., Boston, Mass.	June 11, 1890
Dean, Seth, C. E. Glenwood, Iowa.	Dec. 12, 1888
Dean, William H. Water Analyst, Wilkesbarre, Pa.	Sept. 10, 1898

NAME.	Date of Election.
DeBerard, Wilford W. 116 Pembroke St., Boston, Mass.	Sept. 19, 1900
Decker, J. H. Room 37, Municipal Building, Brooklyn, N. Y.	June 18, 1885
Denman, A. N. Des Moines, Iowa.	June 16, 1886
Denton, J. E. Professor of Experimental Mechanics, Stevens Institute, Hoboken, N. J.	Dec. 11, 1889
Diven, J. M. Supt. Water Co., Elmira, N. Y.	June 16, 1886
Doane, A. O. Engineering Department, Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	Jan. 8, 1896
Doran, Hugh F. Supt. Water Works, Port Huron, Mich.	June 9, 1892
Downey, Wm. 49 Wellington St., Worcester, Mass.	June 14, 1899
Dotten, William T. Supt. Water Works, Winchester, Mass.	June 21, 1882.
Drake, Albert B., C. E. 164 William Street, New Bedford, Mass.	April 21, 1885
Drake, B. Frank Water Commissioner, Lakeport, N. H.	June 16, 1886
Drake, Charles E., C. E. New Bedford, Mass.	Jan. 8, 1890
Drown, Thomas M. President Lehigh University, So. Bethlehem, Penn.	June 13, 1888
Dunbar, E. L. Supt. Water Works, Bay City, Mich.	June 9, 1892
Dyer, Eben R. Supt. of Distribution, Portland, Me.	June 11, 1890
Eardley, B. A. Supt. Pacific Improvement Co. Water Works, Pacific Grove, Monterey County, Cal.	June 15, 1893
Eastman, Henry E. Supt. Water Works, Westport, N. Y.	Sept. 11, 1895

NAME.	Date of Election.
Eddy, Harrison P. Supt. Sewer Department, City Hall, Worcester, Mass.	June 15, 1894
Eglee, Charles H. Hydraulic Engineer, 17 Central Street, Boston, Mass.	June 13, 1889
Eldredge, Edward D. Manager Onset Water Co., 49 Monmouth St., Brookline, Mass.	Feb. 14, 1900
Ellis, George A. Civil Engineer, 158 Sherman St., Springfield, Mass.	June 21, 1883
Ellis, John W. Civil Engineer, Woonsocket, R. I.	Dec. 11, 1889
Ellsworth, Emory A. Civil and Hydraulic Engineer, Holyoke, Mass.	June 10, 1896
Ervin, John Sec'y and Treasurer Middleton Water Supply Co., Bridgeton, N. S.	June 9, 1892
Esterbrook, Arthur F. Water Commissioner, Leicester, Mass.	Sept. 10, 1897
Evans, George E. Civil Engineer, 95 Milk St., Boston, Mass.	Feb. 14, 1888
Evans, Myron Edward Civil Engineer, 20 Nassau St., New York City.	June 13, 1900
Ewell, William Walter Supt. Water Works, Quincy, Mass.	March 9, 1898
Ewing, William B. Civil Engineer, La Grange, Ill.	Dec. 13, 1899
Fairbanks, J. H. Chairman Water Commissioners, Winchendon, Mass.	March 11, 1896
Fales, Frank L. Asst. Engineer, Engineering Dept., Board of Trustees, Commissioners Water Works, Cincinnati, Ohio.	Dec. 13, 1893
Fanning, John T. Consulting Engineer, Kasota Block, Minneapolis, Minn.	April 21, 1885

NAME.	Date of Election.
Farnham, Elmer E. Supt. Water Works, Box 109, Sharon, Mass.	Dec. 11, 1889
Farnum, Loring N. Civil and Hydraulic Engineer, 53 State St., Boston, Mass.	Dec. 13, 1893
Fels, August Water Commissioner, Lowell, Mass.	Sept. 13, 1899
Felton, B. R. Civil Engineer, Tremont Bldg., Boston, Mass.	June 9, 1892
Felton, Charles R. City Engineer, City Hall, Brockton, Mass.	Feb. 16, 1894
Ferguson, John N. Asst. Engineer, Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Dec. 14, 1898
Fifield, John W. D. Water Commissioner, North Brookfield, Mass.	June 15, 1894
Fish, J. B. Superintendent Water Works, Scranton, Pa.	Sept. 11, 1895
Fitch, Jasper A. Supt. Water Company, Manchester, Conn.	June 12, 1890
FitzGerald, Desmond Engineer Sudbury Dept. Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Flinn, Richard J., M. E. West Roxbury Station, Boston, Mass.	Sept. 11, 1895
Fobes, A. A. Engineer Board of Public Works, Pittsfield, Mass.	Feb. 13, 1895
Folwell, A. Prescott Professor of Sanitary and Hydraulic Engineering, Lafayette College, Easton, Pa.	June 15, 1893
Forbes, Fred B. 502 State House, Boston, Mass.	June 14, 1899
Forbes, F. F. Supt. Water Works, Brookline, Mass.	Jan. 29, 1885
Forbes, Murray Manager Westmoreland Water Co., Greensburgh, Penn.	Feb. 11, 1891

NAME.	Date of Election.
Forbes, Z. R. Water Registrar, Brookline, Mass.	Jan. 8, 1890
Foss, William E. Engineers' Dept., Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Foster, Joel Supt. Water Works, Montpelier, Vt.	Sept. 13, 1895
Foye, Andrew E., C. E. Acting Chief Engineer, Dept. of Highways and Viaducts, Greater New York, 21 Park Row, New York City.	Dec. 12, 1894
Freeman, John R. Pres. Factory Insurance Co's, Providence, R. I.	Dec. 12, 1888
French, D. W. Supt. Hackensack Water Co., Box 98, Weehawken, N. J.	June 9, 1892
French, Edward V. Insurance Inspector, 31 Milk St., Boston, Mass.	Sept. 10, 1897
French, Frank Baldwin Engineer and Supt. Board of Public Works, Woburn, Mass.	Sept. 16, 1898
Fteley, Alphonse 14 West 131st Street, New York City.	June 18, 1885
Fuller, Andrew D. 15 Lawrence St., Wakefield, Mass.	Dec. 15, 1899
Fuller, Frank E. P. O. Box 775, West Newton, Mass.	March 14, 1900
Fuller, Frank L. Civil Engineer, 12 Pearl St., Boston, Mass.	June 16, 1886
Fuller, George W. 220 Broadway, New York City.	March 8, 1893
Gage, Stephen DeM. Biologist Mass. State Board of Health.	Jan. 10, 1900
Gamwell, J. H. Treasurer, Water Company, Palmer, Mass.	June 17, 1887
Gardner, L. H. Supt. Water Works Co., New Orleans, La.	June 18, 1885

NAME.	Date of Election.
Gear, Col. A. S. 136 West Broadway, New York City.	Sept. 10, 1897
Geer, Harvey M. Civil Engineer, Balston Spa, N. Y.	Sept. 10, 1897
Gerhard, William Paul Civil Engineer, and Consulting Engineer for Sanitary Works, 36 Union Square, East, New York City.	Dec. 12, 1888
Gerrish, William B. Supt. and Engineer Water Works, Oberlin, O.	Dec. 14, 1892
Gerry, L. L. Civil Engineer, Stoneham, Mass.	Jan. 29, 1885
Gibbs, Harry F. 106 Pond St., Natick, Mass.	Jan. 11, 1899
Gilbert, Julius C. Water Registrar and Treas. Water Works. Whitman, Mass.	June 15, 1894
Gilderson, D. H. Supt. Water Works, Haverhill, Mass.	Sept. 11, 1895
Gleason, Fred B. Inspector, Marlboro, Mass.	Sept. 13, 1895
Gleason, J. F. Foreman of Construction for Water Works, Quincy, Mass.	Feb. 9, 1898
Gleason, T. C. Supt. Water Works, Ware, Mass.	June 15, 1894
Glover, Albert S. Tremont Temple Building, Boston, Mass.	June 21, 1882
Goldthwait, W. J. Marblehead, Mass.	June 11, 1890
Goodnough, X. H. Engineer, State Board of Health, Room 140, State House, Boston, Mass.	Jan. 14, 1891
Gould, Amos A. Water Commissioner, Leicester, Mass.	March 11, 1896
Gould, J. A. Chief Engineer, Brookline and Dorchester Gas Light Companies.	June 14, 1888

NAME.	Date of Election.
Gow, Frederick W. Supt. Water Works, Medford, Mass.	June 11, 1890
Gowing, E. H., C. E. 22 Pemberton Square, Boston, Mass.	April 21, 1885
Graham, James W. Supt. Meter Dept., Portland Water Co., Portland, Me.	Sept. 13, 1895
Greaney, Thomas F. Water Commissioner, Holyoke, Mass.	March 9, 1898
Greene, S. C. Chairman Water Board, St. Albans, Vt.	Sept. 11, 1895
Greetham, H. W. Local Manager Orlando Water & Sewerage Co., Orlando, Florida.	June 13, 1889
Griffin, J. William Care N. Y. & N. J. Water Co., Arlington, N. J.	Dec. 12, 1900
Groce, William R. Supt. Water Works, Rockland, Mass.	Dec. 12, 1888
Gubelman, F. J., C. E. 792 Montgomery St., Jersey City, N. J.	March 11, 1896
Haberstroh, Charles E. Assistant Supt. Metropolitan Water Works, South Framingham, Mass.	Jan. 10, 1900
Haines, William T. Waterville, Me.	Jan. 11, 1899
Hale, Richard A. Principal Assistant Engineer, Essex Company, Lawrence, Mass.	Feb. 14, 1888
Hall, Frank E. Care Sumner & Goodwin Co., 289 Congress St., Boston, Mass.	June 21, 1882
Hall, Hon. John O. 1230 Hancock St., Quincy, Mass.	Dec. 12, 1900
Hammatt, E. A. W. Civil Engineer, 53 State St., Boston, Mass.	June 17, 1887
Hammond, J. C., Jr. Secretary and Treasurer, Rockville Water & Aqueduct Co., Rockville, Conn.	Jan. 11, 1888

NAME.	Date of Election.
Hancock, Joseph C. Supt. Water Works, Springfield, Mass.	June 21, 1882
Hapgood, Lyman P. Supt. Athol Water Co., Athol, Mass.	Nov. 14, 1900
Hardy, J. D. Supt. Water Works, Holyoke, Mass.	March 9, 1898
Haring, James S. Civil Engineer, Crafton, Alleghany Co., Pa.	June 9, 1892
Harlow, James H. President Pennsylvania Water Co., Wilkinsburg, Pa. Address Station D, Pittsburg, Pa.	Sept. 10, 1897
Harrington, Geo. W. Wakefield, Mass.	Dec. 10, 1890
Harris, D. A. Supt. Water Works, New Britain, Conn.	March 14, 1888
Hart, Edward W. General Manager Water Works, Council Bluffs, Iowa.	June 10, 1891
Hartwell, David A. City Engineer, Fitchburg, Mass.	Feb. 16, 1894
Hastings, L. M. City Engineer, Cambridge, Mass.	June 13, 1889
Hastings, V. C. Supt. Water Works, Concord, N. H.	June 10, 1886
Hatch, Arthur Elliott Mechanical Engineer, Bay State Dredging Co., 59 High St., Boston, Mass.	Dec. 11, 1895
Hatch, S. S. Water Commissioner, South Norwalk, Conn.	June 11, 1896
Hathaway, A. R. Water Registrar, Springfield, Mass.	June 10, 1891
Hathaway, James H. Water Registrar, New Bedford, Mass.	June 21, 1882
Hawes, Louis E. Civil and Hydraulic Engineer, Tremont Building, Boston, Mass.	Dec. 12, 1888

NAME.	Date of Election.
Hawes, William B. Water Commissioner, Fall River, Mass.	June 15, 1894
Hawks, William E. Pres. and Treas. Water Co., Bennington, Vt.	Dec. 12, 1894
Hawley, W. C. Supt. Water Dept., Atlantic City, N. J.	Sept. 8, 1897
Hayes, Ansel G. Asst. Supt. Water Works, Box 323, Middleboro, Mass.	June 13, 1889
Hazard, T. G., Jr. Civil Engineer, Narragansett Pier, R. I.	June 15, 1894
Hazen, Allen Civil Engineer, 220 Broadway, New York, N.Y.	June 9, 1892
Heald, Simpson C. Civil Engineer, 48 Congress St., Boston, Mass.	April 21, 1885
Heermans, Harry C. Supt. Water Works, Corning, N. Y.	June 16, 1886
Henderson, Wilson Supt. Water Co., Peterborough, Ontario, Can.	June 17, 1887
Hering, Rudolph Hydraulic, Civil and Sanitary Engineer, 100 William St., New York City.	June 17, 1887
Herschel, Clemens Hydraulic Engineer, 2 Wall Street, Room 68, New York City.	Feb. 10, 1892
Hicks, R. S. 75 Warren St., New York, N. Y.	June 17, 1887
Higgins, James H. Supt. Meter Dept., City Hall, Providence, R. I.	Feb. 8, 1893
Hill, Hibbert Winslow Director Bact. Laboratory Boston Board of Health, 607 Sudbury Building, Sudbury St., Boston.	Sept. 10, 1897
Hill, William R. Chief Engineer Croton Aqueduct Commission, 280 Broadway, New York City.	June 9, 1892

NAME.	Date of Election.
Hodgdon, Frank W. Engineer Mass. Harbor and Land Commission, 131 State House, Boston, Mass.	June 12, 1895
Hodgdon, John S. Wellington, Mass.	June 15, 1894
Holden, Horace G. Supt. Pennichuck Water Works, Nashua, N. H.	June 21, 1882
Hollis, Frederick S. Instructor in Chemistry, Yale Medical School, New Haven, Conn.	Dec. 8, 1897
Holman, M. L. Consulting Engineer, 3744 Finney Avenue, St. Louis, Mo.	June 16, 1886
Hook, G. S. Civil Engineer, 705 Union St., Schenectady, N. Y.	Sept. 13, 1899
Hopkins, Charles C., C. E. Rome, N. Y.	March 10, 1897
Hotchins, Geo. A. Supt. Water Works, Rochester, N. Y.	June 13, 1900
Howard, John L. Assistant Engineer Met. Water Board, No. 1 Ashburton Place, Boston, Mass.	Jan. 10, 1900
Hubbard, Winfred D. Supt. Water Works, Concord, Mass.	Sept. 19, 1900
Hubbell, Clarence W. Water Office, Detroit, Mich.	Sept. 13, 1899
Hunking, Arthur W. 374 Stevens St., Lowell, Mass.	June 11, 1890
Hunter, Henry G. Civil Engineer, Quincy, Mass.	March 13, 1895
Huntington, James A. Water Registrar, Haverhill, Mass.	Dec. 9, 1891
Hyde, Horatio N. Newton ve, Mass.	June 21, 1882
Illig, Frank J. Supt. Water Dept., Buffalo, N. Y.	Sept. 13, 1899

NAME.	Date of Election.
Jackson, Daniel D. Chemist Division of Water Supply, Mt. Prospect Laboratory, Brooklyn, N. Y.	March 14, 1894
Jackson, William City Engineer, City Hall, Boston, Mass.	June 11, 1890
Johnson, H. R. Water Commissioner, Reading, Mass.	Dec. 14, 1898
Johnson, William S. Assistant Engineer State Board of Health, Room 140, State House, Boston, Mass.	Jan. 10, 1894
Jones, A. J. New Brunswick, N. J.	Dec. 14, 1887
Jones, James A. Water Registrar, Stoneham, Mass.	March 14, 1894
Jones, R. A. Civil Engineer, Spokane, Washington.	June 17, 1887
Jordan, John N. Supt. Water Works, Malden, Mass.	June 12, 1896
Judkins, Fred G. Franklin Falls, N. H.	Feb. 14, 1899
Kay, J. William Supt. Water Works, 75 Congress St., Milford, Mass.	Jan. 9, 1901
Kent, E. W. Civil Engineer, Woonsocket, R. I.	Feb. 8, 1893
Kent, Willard Manager Water Company, Narragansett Pier, R. I.	April 21, 1885
Kieran, Patrick Supt. Water Works, Fall River, Mass.	June 16, 1886
Kilbourn, Wm. A. Secretary (Lancaster) Water Commissioners, South Lancaster, Mass.	Dec. 13, 1899
Killam, James W. Metropolitan Water Board, Reading, Mass.	Dec. 13, 1899
Kimball, Frank C. Supt. Knoxville Water Co., 619 South Gay St., Knoxville, Tenn.	Feb. 12, 1896

NAME.	Date of Election
Kimball, George A. Chief Engineer Elevated Lines Boston Elevated Railway, Member Metropolitan Sewerage Board, 101 Milk St., Boston, Mass.	June 17, 1887
Kimball, William L. 241 Columbus Avenue, Boston, Mass.	Dec. 13, 1899
Kingman, Horace Supt. Water Works, Brockton, Mass.	June 15, 1893
Kinnicutt, Leonard P. 77 Elm Street, Worcester, Mass.	Feb. 8, 1893
Kinsey, Warren R. Civil Engineer, 108 Fulton Street, New York City.	Sept. 11, 1895
Knapp, Louis H. Engineer Buffalo Water Works, 280 Linwood Avenue, Buffalo, N. Y.	June 17, 1887
Knight, Charles William, C. E. Rome, N. Y.	March 10, 1897
Knowlton, Charles F Commissioner of Public Works, Quincy, Mass.	Sept. 19, 1900
Knowles, Morris Assistant Engineer in charge of Testing Station, Spring Garden Water Works, Philadelphia, Pa.	June 12, 1895
Koch, Harry G. Supt. Castle Creek Water Company, Aspen, Col.	Dec. 11, 1889
Kuehn, Jacob L. Supt. Water Co., York, Pa.	June 9, 1892
Kuichling, Emil Consulting Engineer, Rochester, N. Y.	Sept. 10, 1897
Laforest, J. O. Alfred Chief Engineer Laurentian Water & Power Co., La Presse Bldg., Montreal, Quebec.	Dec. 14, 1892
Laing, W. H. Secretary and Supt., Racine Water Co., Racine, Wis.	June 13, 1889
Lansing, Edward T. E. Civil Engineer, Little Falls, N. Y.	June 13, 1889

NAME.	Date of Election
Larned, Edward S. Metropolitan Water Supply, South Framingham, Mass.	Jan. 10, 1900
Lautz, Adolphe W. Secretary Water Co., Pekin, Ill.	Sept. 16, 1898
Lawton, Perry Civil Engineer, Savings Bank Building, Quincy, Mass.	Feb. 16, 1894
Lea, R. S. Assistant Professor of Civil Engineering, McGill University, Montreal, P. Q.	June 15, 1893
Learned, Wilbur F. Civil Engineer, Watertown, Mass.	April 21, 1885
Linsley, J. H. 196 Main St., Burlington, Vt.	March 8, 1899
Livermore, N. B. 320 Sansom St., San Francisco, Cal.	Feb. 14, 1900
Locke, James W. Foreman, Brockton, Mass.	Jan. 9, 1895
Lord, Harry A. Supt. Water Works, Ogdensburg, N. Y.	Sept. 8, 1897
Loretz, Arthur J. L. Mechanical Engineer, 150 Nassau Street, New York City.	Dec. 9, 1896
Lovell, Thomas C. Supt. Water Works, 104 River Street, Fitchburg, Mass.	June 21, 1882
Loweth, Charles F. 94 East 4th Street, St. Paul, Minn.	Jan. 9, 1901
Luce, Francis H. Supt. Woodhaven Water Supply Co., Woodhaven, N. Y.	June 12, 1896
Ludlow, J. L. 434 Summit Street, Winston, N. C.	Feb. 14, 1900
Lunt, Cyrus M. Supt. Water Works, Lewiston, Me.	Dec. 9, 1896

NAME.	Date of Election.
Lusk, James L. Major Corps of Engineers, U. S. Army, Washington, D. C.	March 13, 1889
Luther, William J., C. E. Asst. Supt. Attleboro Gas Light Co., Attleboro, Mass.	June 15, 1893
MacMurray, J. C. President and General Manager Cherryvale (Kan.) Water Company, 33 Oak Ave., Worcester, Mass.	Dec. 9, 1896
Mann, Thomas W. Civil Engineer, Holyoke, Mass.	June 9, 1892
Manning, George E. Civil Engineer, New London, Conn.	March 9, 1898
Marble, Arthur D. City Engineer, Lawrence, Mass.	Feb. 12, 1896
Marion, J. A. Civil Engineer, New York Life Building, Montreal, P. Q.	Dec. 13, 1893
Martin, A. E. Supt. Water Company, South Framingham, Mass.	April 21, 1885
Martin, Cyrus B. Treas. Water Co., Norwich, N. Y.	June 17, 1887
Marvell, Edward I. Civil Engineer, 81 Bedford St., Fall River, Mass.	Jan. 13, 1897
Mason, William P. Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.	Dec. 11, 1895
Mather, Nelson E. Supt. Water Works, Clinton, Mass.	Sept. 19, 1900
Mattice, Asa M. Chief Engineer Westinghouse Electric and Mfg. Co., East Pittsburg, Pa.	June 15, 1894
Maybury, William E. Supt. Water Works, Braintree, Mass.	Jan. 9, 1901
Maxcy, Josiah S. Treas. Madison Water Company, Gardiner, Me.	Dec. 14, 1887

NAME.	Date of Election.
McCarthy, Daniel B. Supt. Water Works Co., Waterford, N. Y.	Sept. 11, 1895
McClintock, W. E. Member of Massachusetts Highway Commission, 15 Court Square, Boston, Mass.	June 17, 1887
McClure, Frederick A. City Engineer, Worcester, Mass.	June 15, 1894
McConnell, B. D. Civil Engineer, 185 St. James St., Montreal, P. Q.	June 12, 1890
McDonald, M. L. Supt. and Secretary Water Works, Santa Rosa, Cal.	Sept. 11, 1895
McIntosh, H. M. City Engineer, Burlington, Vt.	Sept. 11, 1895
McKenzie, Theodore H. Manager Water Works, Southington, Conn.	June 12, 1890
McKenzie, Thomas Superintendent Water Works, Box 712, Westerly, N. Y.	Dec. 12, 1894
McMillen, Norman A. Supt. Water Works, North Billerica, Mass.	June 13, 1900
McNally, William 64 Chestnut Street, Marlboro, Mass.	June 11, 1890
Mead, Daniel W. 605 First National Bank Building, Chicago, Ill.	Sept. 19, 1900
Merrill, Frank E. Water Commissioner and Supt. Water Works, Somerville, Mass.	Dec. 9, 1896
Merritt, D. S. Engineer and Supt. Water Works, Tarrytown, N. Y.	Dec. 13, 1893
Metcalf, Leonard Civil Engineer, 14 Beacon St., Boston, Mass.	Feb. 10, 1897
Metcalfe, Henry President Water Board, Cold Spring, N. Y.	June 10, 1896

NAME.	Date of Election.
Miller, A. M. Lieut.-Col. Corps of Engineers, U. S. A., 2728 Pennsylvania Avenue, Washington, D. C.	Nov. 14, 1900
Miller, John F. Assistant Sec'y Westinghouse Air Brake Co., East Pittsburg, Pa.	June 10, 1896
Miller, P. Schuyler 108 Park Place, Brooklyn, N. Y.	Jan. 10, 1900
Mills, Frank H. City Engineer, Woonsocket, R. I.	Jan. 14, 1891
Mirick, George Langdon Civil Engineer, 104 Porter St., Malden, Mass.	June 15, 1893
Molis, William Supt. Water Works Co., Muscatine, Iowa.	June 17, 1887
Mullhall, John F. J. Treas. Portland (Ct.) Water Co., 11 Beacon St., Boston, Mass.	Nov. 14, 1900
Murdoch, William Supt. Water Works, St. John, N. B.	Jan. 10, 1900
Myers, J. H., Jr. Asst. Engineer N. Y. Rapid Transit R. R. Commission, 90 Pierrepont St., Brooklyn, N. Y.	Sept. 11, 1895
Nash, H. A., Jr. Civil Engineer, Weymouth Heights, Mass.	March 13, 1895
Naylor, Thomas Supt. Water Works, Maynard, Mass.	Feb. 16, 1894
Nettleton, Charles H. Treasurer and Supt. Water Co., Birmingham, Conn.	June 16, 1886
Newhall, John B. 184 Bay Street, Stapleton, Staten Island.	Dec. 14, 1892
Nichols, Thomas P. Member Water Board, 11 Prospect St., Lynn, Mass.	Jan. 10, 1894
Northrop, Frank L. P. O. Box 1566, Saco, Me.	June 15, 1893

NAME.	Date of Election.
Nuebling, Emil L. Engineer and Supt. Water Dept., Reading, Penn.	Feb. 12, 1896
Nye, George H. Civil Engineer, New Bedford, Mass.	March 11, 1891
Nye, Joseph K. President Water Company, Fairhaven, Mass.	March 8, 1893
O'Connell, P. D. Supt. Water Works, Somersworth, N. H.	Sept. 16, 1898
Paine, C. W. Constructing Engineer on Extension of Butte City Water Works, Lewisohn Building, Butte, Mont.	Dec. 12, 1888
Parker, Charles B., Asst. Supt. Water Works, Cambridge, Mass.	Jan. 9, 1901
Parker, Horatio N. Biologist Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	March 10, 1897
Parks, Charles F. Civil Engineer, 11 Beacon St., Boston, Mass.	Dec. 11, 1889
Parsons, Frank N Clerk Water Board, Franklin, N. H.	March 9, 1892
Patch, Walter Woodbury Civil Engineer, Eastern Avenue, So. Framingham, Mass.	June 12, 1895
Paulison, Washington Supt. Acquackanonk Water Co., Passaic, N. J.	Sept. 16, 1898
Payson, E. R. Secretary Portland Water Co., Portland, Me.	June 13, 1900
Pease, A. G. Water Commissioner, Spencer, Mass.	June 16, 1886
Peene, Edward L. Supt. Water Works, Yonkers, N. Y.	Sept. 16, 1898
Peirce, Charles E. Supt. East Providence Water Co., East Providence Centre, R. I.	Sept. 14, 1887
Perkins, John H. Supt. Watertown and Belmont Water Works, Watertown, Mass.	June 16, 1886

NAME.	Date of Election
Perry, Fred G. Pawtucket, R. I.	Feb. 13, 1895
Phillips, Edward Civil Engineer, No. 11 Broadway, N. Y.	Dec. 8, 1897
Pierce, Frank L. 464 Elm St., Richmond Hill, Queens County, N. Y.	Dec. 14, 1898
Pitman, Winthrop M. Treasurer North Conway Water and Improvement Co. Address 493 Centre Street, Jamaica Plain, Mass.	June 17, 1887
Pitney, Frederic V. Engineer, Morristown Aqueduct Co., Morristown, N. J.	Feb. 16, 1894
Pittman, William General Manager Water Works, Box 305, Jerseyville, Ill.	Dec. 9, 1891
Pollard, William D. General Manager Water Co., Pottsville, Pa.	June 10, 1891
Porter, Dwight Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Boston, Mass.	March 13, 1889
Potter, Alexander Civil and Sanitary Engineer, 137 Broadway, New York City.	March 14, 1894
Poussin, Ludovic de la Vallee Constructing Engineer, P. O. Box 1144, Montreal, P. Q.	June 15, 1894
Pratt, Charles W. Utica, N. Y.	June 11, 1890
Probst, C. O. Secretary State Board of Health, Columbus, Ohio.	Dec. 8, 1897
Putnam, J. B. Supt. Westboro Water and Sewer Depts., Westboro, Mass.	Sept. 10, 1897
Rawson, Waldo E. Supt. Water Works, Uxbridge, Mass.	June 9, 1892

NAME.	Date of Election.
Reed, D. A. Civil and Hydraulic Engineer, 312 Providence Building, Duluth, Minn.	Feb. 6, 1894
Reynolds, E. H. Brockton, Mass.	June 9, 1892
Rice, George S. Deputy Chief Engineer Rapid Transit Railroad Commissioners, 320 Broadway, New York City.	Dec. 14, 1892
Rice, James L. Supt. Water Co., Claremont, N. H.	June 15, 1894
Rice, L. Frederick Architect and Civil Engineer, 125 Milk St. Boston, Mass.	June 17, 1887
Richards, H. DeC. Manager Water Works, 123 Liberty Street, New York City.	June 10, 1896
Richards, Walter H. Supt. Water Works, New London, Conn.	Oct. 11, 1882
Richardson, Charles W. Water Commissioner, 8 High Street, Everett, Mass.	March 13, 1895
Richardson, T. F. Dept. Engineer Metropolitan Water Board, Clinton, Mass.	Feb. 10, 1897
Ridpath, J. W. Secretary and Manager Water Company, Jenkintown, Pa.	June 9, 1892
Ries, George J. Supt. Water Works, Weymouth Centre, Mass.	June 16, 1886
Riley, Charles E. Member Water Board, Brookline, Mass.	Sept. 13, 1899
Ringrose, J. W. New Britain, Conn.	Feb. 14, 1888
Robbins, F. H. Civil Engineer, 1 Ashburton Place, Boston, Mass.	Sept. 10, 1897

NAME.	Date of Election
Roberts, Vaughn M. Civil Engineer, 700-701 Lewis Block, Pittsburg, Pa.	Dec. 13, 1893
Robertson, George H. Supt. Water Works, Yarmouth, N. S.	June 9, 1892
Robertson, W. W. Water Registrar, Fall River, Mass.	June 17, 1887
Robinson, A. Supt. Water Works, Benicia, Cal.	June 11, 1896
Roden, Thomas Supt. Water Works, Arlington, Mass.	June 12, 1896
Rogers, Henry W. 62 Arlington St., Haverhill, Mass.	June 21, 1882
Rogers, Thomas H. Pumping Engineer, Pennichuck Water Works, Nashua, N. H.	Sept. 8, 1897
Rotch, William Civil Engineer, Room 742, Exchange Building, 53 State St., Boston, Mass.	June 16, 1886
Roullier, G. A. Supt. Water Works, Flushing, N. Y.	June 13, 1889
Royce, Harley E. Assistant Engineer, Brookline, Mass.	Jan. 9, 1895
Russell, A. N. Pres. Water Commissioners, Illion, N. Y.	Sept. 13, 1899
Russell, Daniel Everett, Mass.	June 19, 1884
Salisbury, A. H. Supt. Water Works, Lawrence, Mass.	Jan. 11, 1888
Sanborn, Willard T. Supt. Water Works, 87 Portland St., Dover, N. H.	March 14, 1894
Sanders, George O. Pres. Water Works Co., Hudson, N. H.	Jan. 13, 1892
Sando, W. J. Manager Water Works Dept., International Steam Pump Co., Brooklyn, N. Y.	June 12, 1895

NAME.	Date of Election.
Saville, Caleb M. Engineering Dept. Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Sawyer, Frederick W. Water Registrar, Milford, N. H.	Dec. 9, 1891
Sears, Walter H. 220 Sandwich St., Plymouth, Mass.	Sept. 13, 1899
Sealy, W. F. P. Supt. Water Works, Potsdam, N. Y.	Sept. 13, 1895
Sedgwick, William T. Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.	Feb. 12, 1890
Sharples, Philip P. 22 Concord Avenue, Cambridge, Mass.	June 14, 1899
Shedd, Edward M. Inspector Water Works, Somerville, Mass.	Jan. 9, 1901
Shedd, Edward W. Civil Engineer, 146 Westminster St., Providence, R. I.	March 9, 1892
Shedd, J. Herbert Consulting Engineer, Providence, R. I.	June 13, 1888
Shepard. F. J. Treasurer Water Co., Derry, N. H.	June 15, 1893
Sherman, Charles W. Civil Engineer, Assistant Engineer Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Sept. 10, 1897
Sherman, William B. Mechanical Engineer, Box 974, Providence, R. I.	Oct. 11, 1882
Sherrerd, Morris R. Engineer Water Dept., Newark, N. J.	March 10, 1897
Shippee, John D. Holliston, Mass.	Jan. 14, 1891
Shirreffs, Reuben Chief Engineer Virginia Electric Railway and Development Co., Richmond, Va.	March 12, 1890
Sinclair, Melville A. Supt. Water Works, Bangor, Me.	June 15, 1894

NAME.	Date of Election.
Smith, Herbert E. Professor of Chemistry, Yale Medical School, Chemist Conn. St. Board of Health, Address 430 George St., New Haven, Conn.	Dec. 14, 1892
Smith, H. O. Water Commissioner, Leicester, Mass.	June 15, 1894
Smith, John E. Supt. Water Works, Andover, Mass.	June 10, 1896
Smith, J. J. City Engineer, Grand Forks, N. D.	Nov. 14, 1900
Smith, J. Waldo Supt. Passaic Water Co., 109 Washington St., Paterson, N. J.	Dec. 13, 1893
Smith, Sidney Civil Engineer, 91 Maple St, West Roxbury, Mass.	June 12, 1895
Smith, Solon F. Supt. and Treas. Water Co., Grafton, Mass.	June 17, 1887
Snell, George H. Water Commissioner and Supt. Water Works, Attleboro, Mass.	Dec. 12, 1900
Snow, Edwin W. 14 Carleton Street, Somerville, Mass.	June 15, 1894
Soper, George A. 29 Broadway, New York City.	Jan. 12, 1898
Souther, Henry Water Commissioner, Hartford, Conn.	June 13, 1900
Sparks, H. T. Supt. Water Dept., Public Works Co., Bangor, Me., Address, Box 208, Brewer, Me.	June 15, 1894
Springfield, John F. Civil Engineer, 64 Summer Street, Rochester, N. H.	Jan. 13, 1892
St. Louis, J. A. Water Registrar, Marlborough, Mass.	Sept. 10, 1897
Stacy, George A. Supt. Water Works, Marlborough, Mass.	April 21, 1885
Starr, William W. Civil Engineer, 304 Court Exchange Building, Bridgeport, Conn.	Jan. 14, 1891

NAME.	Date of Election.
Stearns, Frederic P. Chief Engineer Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	June 17, 1887
Stevenson, Harry W. 31 Waterford St., Lowell, Mass.	Sept. 21, 1900
Stoddard, S. G., Jr. Supt. and Engineer Bridgeport Hydraulic Co. 323 Water Street, Bridgeport, Conn.	June 9, 1892
Stone, Charles A. Electrical Engineer, 4 Postoffice Square, Boston, Mass.	June 15, 1894
Stubbs, J. H. With Metropolitan Sewerage Commission, 20 Pemberton Sq., Boston, Mass.	Sept. 13, 1899
Street, L. Lee 121 Stoughton St., Dorchester, Mass.	Jan. 10, 1900
Sullivan, John C. Holyoke, Mass.	June 15, 1893
Sullivan, J. J. Water Commissioner, Holyoke, Mass.	March 9, 1898
Sullivan, William F. City Engineer's office, Lowell, Mass.	Feb. 14, 1900
Sutherland, D. A. Supt. Water Works, Lynn, Mass.	Feb. 8, 1893
Swain, George F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.	June 17, 1887
Swan, Joseph W. Assistant Clerk, Water Commissioners' office, Boston, Mass.	Feb. 11, 1891
Tabb, William B. Guam, P. I.	June 15, 1893
Taber, Robert W. Water Commissioner, New Bedford, Mass.	Sept. 16, 1898
Taylor, Charles N. Wellesley, Mass.	Feb. 13, 1901
Taylor, Edwin A. Constructing Engineer, 73 Tremont Street, Boston, Mass.	Dec. 14, 1892
Taylor, Frederick L. Engineer, Brookline Water Works, Brookline, Mass.	Feb. 13, 1895

NAME.	Date of Election.
Taylor, Lucian A. Civil Engineer and Contractor, 73 Tremont St., Boston, Mass.	June 19, 1884
Tenney, D. W. Methuen, Mass.	June 10, 1896
Tenney, Joseph G. Treas. and Supt. Water Works, Leominster, Mass.	June 21, 1882
Thomas, Robert J. Supt. Water Works, Lowell, Mass.	June 9, 1892
Thomas, Harry L. Asst. Supt. Water Co., Hingham, Mass.	Dec. 14, 1898
Thomas, William H. Supt. Water Co., Hingham, Mass.	Dec. 14, 1887
Thomson, John Hydraulic Engineer, 253 Broadway, New York City.	June 9, 1892
Tighe, James L. Engineer Water Works, Holyoke, Mass.	March 9, 1898
Tingley, R. H. Civil Engineer, 75 Westminster St., Providence, R. I.	Feb. 8, 1893
Tinkham, S. Everett Assistant Engineer, Engineering Dept., City Hall, Boston, Mass.	Jan. 14, 1891
Tompkins, Charles H. Civil Engineer, 120 Liberty Street, New York City.	Dec. 11, 1889
Tower, D. N. Supt. Water Co., Cohasset, Mass.	June 17, 1887
Travis, George W. Supt. Water Works, Natick, Mass.	Dec. 13, 1899
Treman, E. M. Supt. and Secretary, Water Co., Ithaca, N. Y.	June 11, 1890
Tribus, Louis L. Cons. Civil and Hydraulic Engineer, 84 Warren Street, New York City.	March 11, 1896
Turner, H. N. Manager Water Co., St. Johnsbury, Vt.	Dec. 11, 1895

NAME.	Date of Election.
Tuttle, Arthur S. Civil Engineer, Department Water Supply, 82d St., near 11th Ave., Brooklyn, N. Y.	March 14, 1894
Tubbs, J. Nelson General Inspector, Dept. of Public Works, State of New York, 207 Wilder Building, Rochester, N. Y.	June 11, 1890
Vallaincourt, J. A. Asst. Treas. Water Co., Berlin, N. H.	Sept. 13, 1899
Vaughn, W. H. Supt. Water Works, Wellesley Hills, Mass.	Dec. 11, 1889
Venner, John Chief Inspector Bureau of Water, Syracuse, N. Y.	Jan. 11, 1899
Wade, William W. Water Registrar, Woburn, Mass.	Dec. 8, 1897
Walker, Charles K. Supt. Water Works, Manchester, N. H.	June 21, 1882
Walker, John Civil Engineer, Newmarket, N. H.	Dec. 12, 1894
Wallace, E. L. Supt. Water Works, Franklin Falls, N. H.	Dec. 14, 1892
Warde, John S. Supt. Staten Island Water Supply Co., West New Brighton, Staten Island, N. Y.	June 15, 1894
Wardsworth, A. R. Civil Engineer, Farmington, Conn.	June 15, 1894
Warren, H. A. Supt. Water Works, St. Albans, Vt.	Dec. 14, 1892
Webster, F. P. Supt. Water Works Co., Lakeport, N. H.	Jan. 8, 1890
Welch, J. Alfred Taunton, Mass.	Feb. 13, 1895
Westcott, George P. Treasurer Portland Water Co., Portland, Me.	June 16, 1886
Weston, Robert S. Chemist and Bacteriologist, 14 Beacon St., Boston, Mass.	Sept. 8, 1897

NAME.	Date of Election.
Wheeler, Elbert Treasurer Water Company, Knoxville, Tenn., Address, 14 Beacon St., Boston, Mass.	Dec. 9, 1891
Wheeler, Warren B. Assistant City Engineer, Fitchburg, Mass.	Feb. 16, 1894
Wheeler, William Civil Engineer, 14 Beacon St., Boston, Mass.	Dec. 11, 1889
Whipple, George C. Mt. Prospect Laboratory, Flatbush Avenue and Eastern Parkway, Brooklyn, N. Y.	Feb. 8, 1893
Whitcomb, W. H. President Water Co., Norway, Me.	June 16, 1886
Whitham, Jay M. Mechanical Engineer, 607 Bullitt Building, Philadelphia, Pa.	Dec. 13, 1893
Whitman, Herbert T. Civil Engineer, 85 Devonshire Street, Boston, Mass.	Feb. 8, 1893
Whitney, John C. Water Commissioner, Newton, Mass.	June 17, 1887
Whittemore, W. P. Supt. Electric Light and Water Depts., No. Attleboro, Mass.	June 16, 1886
Whittier, Herbert F. 253 Jackson Street, Lawrence, Mass.	Jan. 11, 1888
Wigal, James P. Superintendent and Engineer Water Works, Henderson, Ky.	June 16, 1886
Wilcox, William C. Waltham, Mass.	June 21, 1882
Wilde, George E. Assistant Superintendent Metropolitan Water Works, Medford, Mass.	June 16, 1886
Wilder, Frederick W. Treasurer Aqueduct Company, Woodstock, Vt.	Dec. 12, 1888
Wilkins, Frank B. Supt. Water Works, Milford, N. H.	Feb. 14, 1900

NAME.	Date of Election.
Williams, Gardner S. Engineer in charge of Hydraulic Laboratory, and Prof. of Experimental Hydraulics, Cornell University, Ithaca, N. Y.	June 12, 1895
Williams, William F. City Engineer, New Bedford, Mass.	Feb. 16, 1894
Winslow, C.-E. A. Mass. Inst. of Technology, Boston, Mass.	Sept. 21, 1900
Winslow, Frederic I. Assistant Engineer, City Engineer's office, City Hall, Boston, Mass.	Jan. 13, 1892
Winslow, George E. Waltham, Mass.	June 18, 1885
Winslow, S. J. Superintendent Water Co., Pittsfield, N. H.	June 17, 1887
Wiswall, E. T. West Newton, Mass.	June 13, 1889
Wood, Henry B. Chief Engineer Topographical Survey, Room 138, State House, Boston, Mass.	Dec. 13, 1893
Woodruff, Timothy Supt. Water Works, Bridgeton, N. J.	June 13, 1888
Woods, Henry D. West Newton, Mass.	Jan. 9, 1895
Worthington, E., Jr. Civil Engineer, Dedham, Mass.	Jan. 11, 1893
Wright, George W. Chief Engineer Water Department, Box 426, Norfolk, Va.	June 9, 1892
Yorston, W. G. Constructing Engineer, Box 47 , Truro, N. S.	Dec. 14, 1892
Youngren, Carl J. Boston Water Dept., City Hall, Boston, Mass.	Dec. 13, 1899
Zick, W. G. 253 Broadway, New York City.	June 15, 1893

HONORARY MEMBERS.

NAME.	Date of Election.
Frost, George H. President Engineering News Pub. Co., St. Paul Building, New York City.	June 16, 1886
Gale, James M. Engineer-in-Chief Loch Katrine Water Works, Glasgow, Scotland.	Jan. 16, 1889
Meyer, Henry C. The Engineering Record, 100 William Street, New York City.	June 17, 1887
Shepperd, F. W. "Fire and Water," Bennett Bldg., Nassau and Fulton Streets, New York City.	Feb. 12, 1890

ASSOCIATES.

Allis, The Edward P. Co. "High Duty Pumping Engines," Milwaukee, Wis.	Dec. 13, 1893
Ashton Valve Co. "Water Relief Valves," 271 Franklin Street, Boston, Mass.	June 18, 1885
Barr Pumping Engine Co. Philadelphia, Pa.	Feb. 13, 1901
Betton, James M. Care H. R. Worthington, Box 14, Brooklyn, N. Y.	Dec. 12, 1888
Blake, The George F. Mfg. Co. "Pumping Engines," 54 Oliver Street, Boston, Mass.	June 21, 1883
Bond & Co., Harold L. 140 Pearl Street, Boston, Mass.	Dec. 12, 1900
Boston Lead Mfg. Co. 162 Congress Street, Boston, Mass.	April 21, 1885
Brandt, Randolph "Selden Patent Packing," 38 Cortlandt Street, New York City.	April 21, 1885
Brewster, H. M. (E. Stebbens Mfg. Co.) "Brass Goods," Brightwood P. O., Springfield, Mass.	June 13, 1888

NAME.	Date of Election
Builders' Iron Foundry P. O. Box 218, Providence.	June 17, 1887
Chadwick Lead Works 176 to 183 High Street, Boston, Mass.	April 21, 1885
Chapman Valve Mfg. Co. "Valves and Hydrants," Indian Orchard, Mass.	June 21, 1883
Claflin, Chas. A. Steam Engineering & Water Works Supplies, 188 Franklin Street, Boston, Mass.	Jan. 9, 1901
Coffin Valve Co. "Valves and Hydrants," Neponset, Boston, Mass.	June 16, 1886
Davidson, M. T. "Steam Pumps," 43 and 53 Keap Street, Brooklyn, N. Y.	June 19, 1882
Deane Steam Pump Co. "Steam Pumps and Pumping Machinery," Holyoke, Mass.	April 21, 1885
Dibble, F. J. "Electric Gauges," Peabody, Mass.	June 11, 1890
Drummond, M. J. "Cast Iron Pipe," 192 Broadway, Corbin Building, New York City.	Dec. 14, 1887
Dunne, George C. Manager Portland Stoneware Co., 42 Oliver Street, Boston, Mass.	Feb. 10, 1892
Eagle Oil & Supply Co. 104 Broad Street, Boston, Mass.	June 15, 1894
Fairbanks Co., The "Valves," 38 to 44 Pearl Street, Boston, Mass.	March 12, 1890
Garlock Packing Co., "Packing," 12 Pearl Street, Boston, Mass.	June 11, 1896
Gallison, William H. Co. "Engineer's Supplies, Pipe, etc.," 36 Oliver Street, Boston, Mass.	June 18, 1885
General Manufacturing Co. "Pumping Engines and Hydraulic Specialties," 275 Clinton Avenue, Brooklyn, N. Y.	June 15, 1894

NAME.	Date of Election.
Gilchrist, George E. "Pipes and Fittings," 106 High, corner Congress Street, Boston, Mass.	Jan. 11, 1888
Goulds Mfg. Co., The "Engines," 236 Congress Street, Boston, Mass.	Sept. 11, 1895
Helmer, W. K. Agent Holly Manufacturing Co., Lockport, N.Y.	Sept. 8, 1897
Hersey Manufacturing Co. "Meters," South Boston, Mass.	June 16, 1886
Holly Manufacturing Co. "Pumping Machinery," Lockport, N. Y.	June 10, 1891
Jenks, Henry F. "Drinking Fountains," Pawtucket, R. I.	April 21, 1885
Kennedy Valve Co. "Valves, Hydrants, and Indicating Devices," 57 Beekman and 87 Ann St., New York City.	Sept. 8, 1897
Lamb & Ritchie, Tin-lined Iron Pipe, and Lead-ined Iron Pipe, Cambridge, Mass.	Dec. 12, 1900
Lead Lined Iron Pipe Co. "Lead and Tin Lined Pipe," Wakefield, Mass.	Sept. 8, 1897
Libbey, Parker & Co. "Plumbing, Steam, Water Works Specialties and Supplies," 416 Atlantic Avenue, Boston, Mass.	March 14, 1900
Ludlow Valve Mfg. Co. "Valves and Hydrants," 150 High St., Boston, Mass.	June 18, 1885
Lynch, John E. Proprietor "E. Hodge & Co., Stand Pipes," East Boston, Mass.	June 10, 1891
Michigan Brass and Iron Works. "Valves, Hydrants, and Brass Goods," Detroit, Mich.	June 13, 1889
Moore, Charles A. "Engines, Boilers, and Supplies," 85 Liberty Street, New York City.	Dec. 9, 1896
Morris, I. P. Co. "Pumping Engines and Turbines," cor. Beach and Ball Streets, Philadelphia, Pa.	June 15, 1894

NAME.	Date of Election.
Mueller, H. Mfg. Co. "Water Works Supplies," Decatur, Ill.	Sept. 11, 1895
National Lead Co. (Boston Branch) 89 State Street, Boston, Mass.	March 14, 1894
National Meter Co. "Meters," 84 Chambers Street, New York City.	Oct. 11, 1882
National Tube Co. "Pipe and Fittings," McKeesport, Penn. Address 95 Milk Street, Boston, Mass.	April 21, 1885
Neptune Meter Co. "Trident Water Meters," Jackson Avenue and Crane Street, Long Island City, New York.	June 15, 1893
New York Filter Mfg. Co. "Filters," 15 Broad St., New York City.	June 15, 1894
Norwood Engineering Co. "Hydrants, Filters, etc.," Florence, Mass.	April 21, 1885
Peck Bros. & Co. "Water Works Supplies," 65 Oliver Street, Boston, Mass.	Dec. 12, 1894
Perrin, Seamans & Co. "Construction Tools and Supplies," 57 Oliver Street, Boston, Mass.	June 11, 1890
Pittsburg Meter Co. "Water Meters," East Pittsburg, Penn.	June 15, 1894
Rensselaer Mfg. Co. "Valves and Water Gates, and sole Mfgrs. of Corey Fire Hydrant," Troy, N. Y.	June 11, 1890
Roberts, C. E. Hartford Steam Boiler Inspection and Insurance Company, 125 Milk Street, Telephone Building, Boston, Mass.	March 13, 1889
Robinson, Edward "Wells Light Mfg. Co.," 44-46 Washington St., New York City.	Dec. 13, 1899
Ross Valve Co. "Valves," Troy, N. Y.	June 13, 1888
Sampson, George H. "Powder," 13 Pearl Street, Boston, Mass.	June 18, 1885

NAME.	Date of Election.
Smith, A. P. Mfg. Co. "Tapping Machines," Passaic Avenue, foot of Brill Street, Newark, N. J.	Feb. 10, 1892
Smith, Benjamin C. "Water Works Supplies," 275 Pearl Street, New York City.	June 15, 1893
Smith, B. F. & Bro. "Artesian and Driven Wells," 38 Oliver Street, Boston, Mass.	Sept. 10, 1897
Snow, Franklin A. Civil Engineer and Contractor, 490 Broad St., Providence, R. I.	Jan. 10, 1894
Snow Steam Pump Works, The "Steam Pumps," Buffalo, N. Y.	Dec. 12, 1894
Sumner & Goodwin Co. "Water Works Supplies," 287 Congress Street, Boston, Mass.	April 21, 1885
Sweet & Doyle, Selling Agents "Vincent Valves," Cohoes, N. Y.	June 13, 1900
Thomson Meter Co. "Water Meters," 79 Washington Street, Brooklyn, N. Y.	June 13, 1888
Union Water Meter Co. "Water Meters," 31 Hermon Street, Worcester, Mass.	June 21, 1883
United States Cast Iron Pipe & Foundry Co. Cor. Broad and Chestnut Sts., Philadelphia, Pa.	Sept. 13, 1899
Waldo Bros. "Contractors' Supplies," 102 Milk Street, Boston, Mass.	April 21, 1885
Walworth Mfg. Co. "Pipe, Brass Work, Service Boxes, etc.," 134 Federal Street, Boston, Mass.	April 21, 1885
Wilfendale, William Agent for Plumbers' Supplies, 76 Second Street, Fall River, Mass.	June 13, 1889

NAME.	Date of Election.
Wood, R. D. & Co. "Cast Iron Pipe," 400 Chestnut Street, Philadelphia, Penn.	June 19, 1884
Woodman Co., The George "Pipe and Fittings," 41 Pearl Street, Boston, Mass. P. O. Box 3653.	April 21, 1885
Worthington, H. R. "Pumping Engines," Hydraulic Works, South Brooklyn, N. Y.	June 19, 1884

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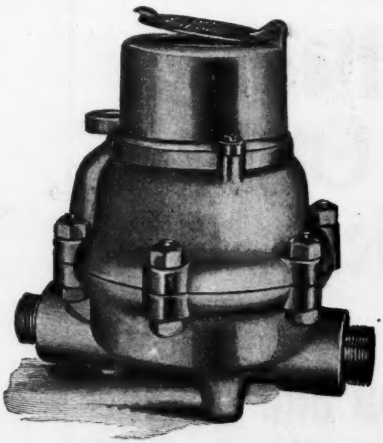

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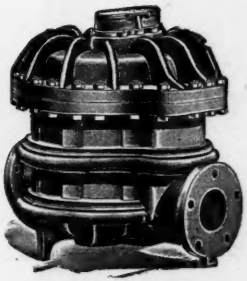

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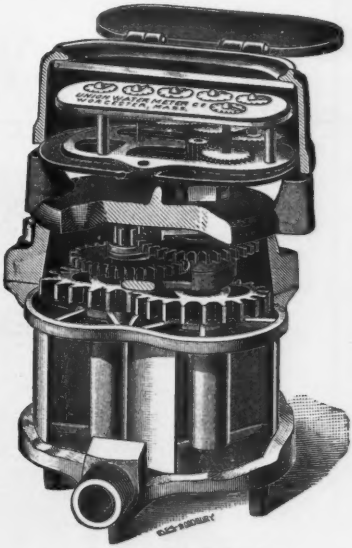

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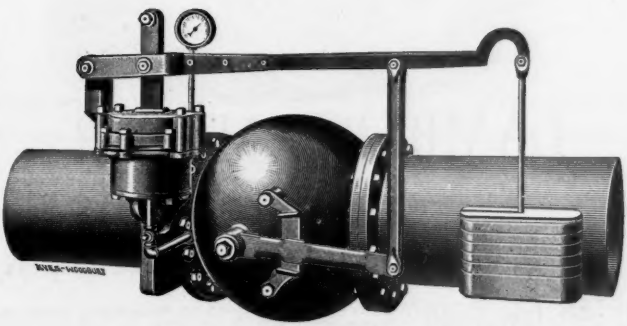

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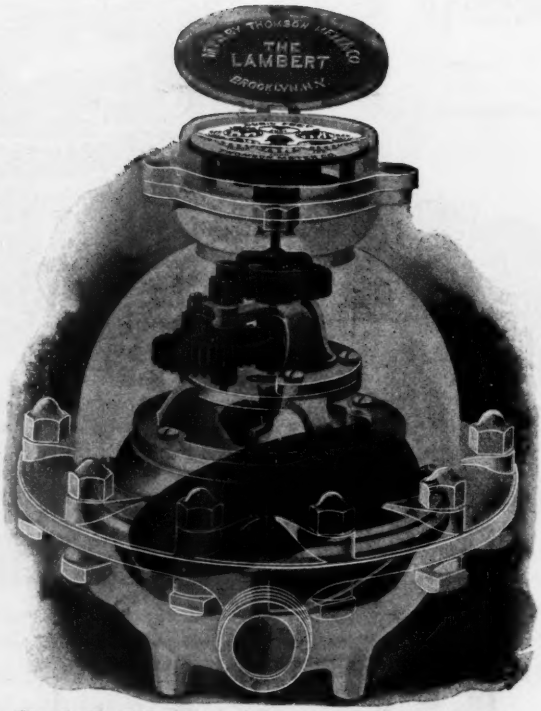

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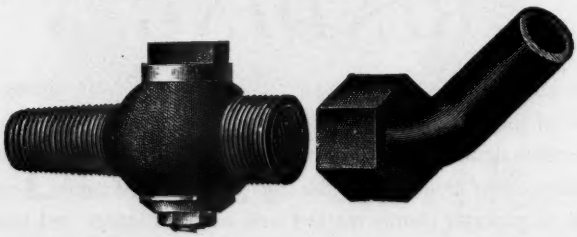

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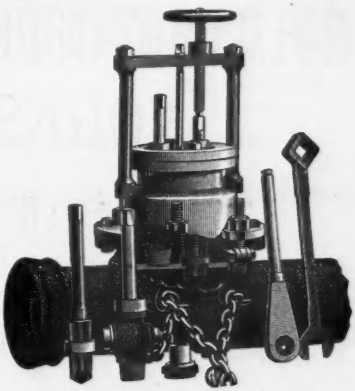

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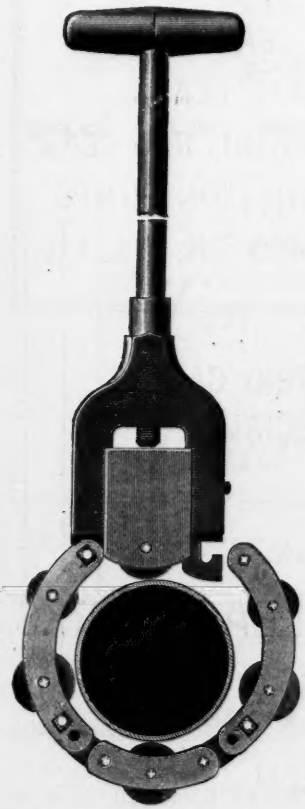

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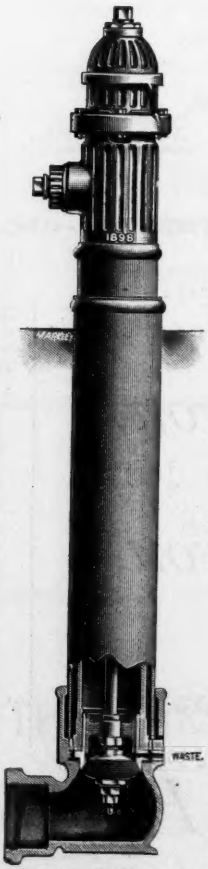

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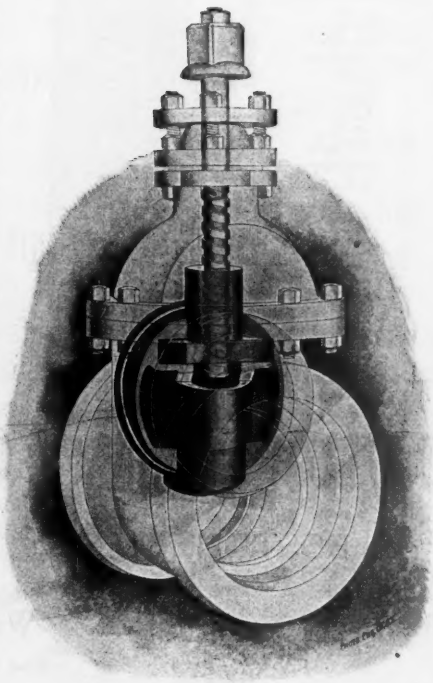

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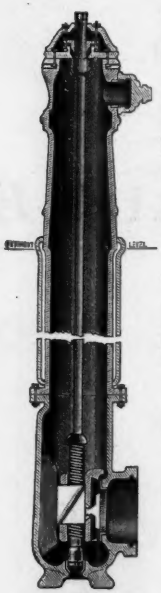

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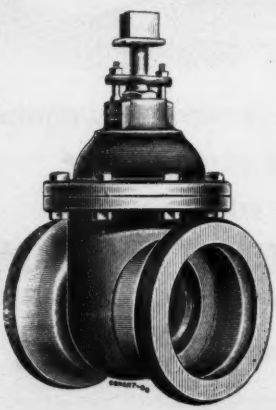

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National Foundry and Pipe Works, Scottdale, Pa. (Limited.)
McNeal Pipe and Foundry Company, Burlington, N. J.
Wisconsin Steel Company, West Superior, Wis.
American Pipe and Foundry Company, Chattanooga, Tenn. (With foundries at Bessemer, Ala.; Annistown, Ala.; Bridgeport, Ala.; Chattanooga, Tenn.; and South Pittsburg, Tenn.)

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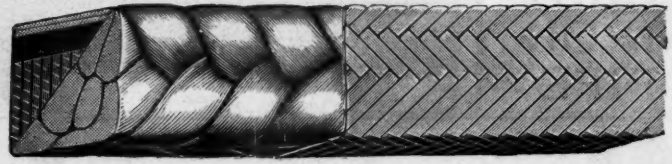

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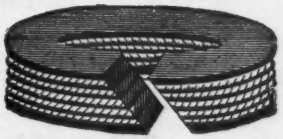

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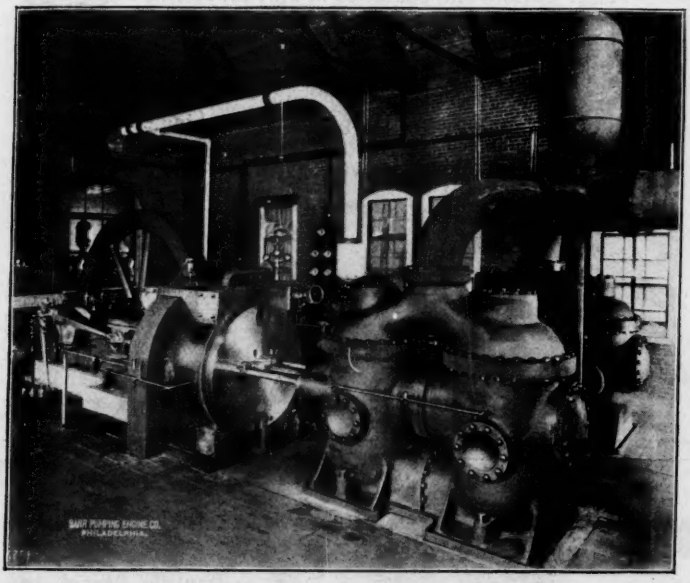

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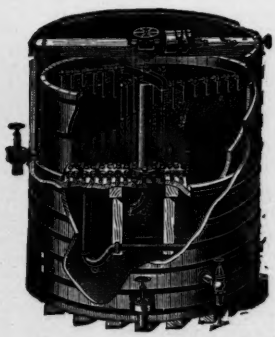

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